Illuminating Engineering

TRANSACTIONS

OF THE

ILLUMINATING ENGINEERING SOCIETY

VOL. VIII

JANUARY-DECEMBER

1913

Subject Index and Index to Authors

ILLUMINATING ENGINEERING SOCIETY
29 WEST THIRTY-NINTH STREET
NEW YORK

SUBJECT INDEX.

* Pages following the numbers given should be consulted in referring to a topic or subject.

INDEX TO AUTHORS

The letter d indicates discussion.

TRANSACTIONS
OF THE
Illuminating Engineering Society

Published on the 28th of each month, except during July, August, and September, by the
ILLUMINATING ENGINEERING SOCIETY
General Offices: 29 West Thirty-Ninth Street, New York

Vol. VIII JANUARY, 1913 No. 1

Index for Volume VII.

The index for Volume VII (1912) of the Transactions will be mailed in separate form with the February issue which will be out about the middle of March.

The New Transactions.

In this issue an attempt has been made to improve the general make-up of the Transactions. Dull finished paper, free from the objectionable glare which a reader usually encounters in magazines and books, has been used throughout. This number also has a more appropriate cover. Other improvements, in the way of better arrrangement and presentation of subject matter, more legible type, and the like, may be expected later. Such changes will ultimately afford a more commendable publication which, it is hoped, will be of greater interest to the members of the society and more valuable as a journal of reference for libraries. Beginning with the April issue each number of the Transactions will be published on the 28th of the month.

Annual Committee Reports.

Below are given synopses of the annual reports of committees, which were presented at a meeting of the council held in New York, January 10, 1913.

FINANCE COMMITTEE

All the bills for the year were approved by the committee. A report on the books of account for 1912 prepared by Wm. J. Struss & Company, certified public accountants, accompanied the committee's report. This report showed a deficit of $640.07 for the year, and an impairment of surplus amounting to $1,435.63. The average expense per member was estimated as $7.36. The report appears in full elsewhere in this issue of the Transactions.

COMMITTEE ON ILLUMINATION PRIMER

This report is supplementary to the report of the committee in the June (1912) Transactions. Ten thousand primers (Light: Its Use and Misuse) had been published, and an edition of 5,000 is now on the press. About 5,500 copies have been distributed free by the society, 4,000 have been sold and delivered, and orders are on hand for 4,500. Forty-five lighting companies scattered throughout the country have purchased copies mostly in lots of 25, 50 and 100. Orders have been received from a number of manufacturers of lamps and lighting appliances, from contractors and from several colleges. The primer was reprinted in full in journals whose combined circulation is about 30,000; abstracts have appeared in more than 150

domestic and foreign journals; it was estimated that altogether about 2,000,000 notices of the primer have been printed by these journals. The primer was published in England in a modified form. A much wider and more general distribution or circularization is very probable.

COMMITTEE ON FACTORY LIGHTING LEGISLATION

The committee, although it had been appointed recently, drafted and submitted to the New York Investigating Commission recommendations on sections 3 and 4 of proposed Bill No. 18 pertaining to the lighting of factories and work-rooms. These recommendations having to do with specifications for proper and adequate lighting were made principally in the interests of ocular hygiene and safety of employees. The bill in its final form will be printed in a future issue of the TRANSACTIONS.

COMMITTEE ON GLARE FROM REFLECTING SURFACES

This committee had been in existence only a short time. In the course of its work it learned (1) that school-book publishers are in favor of eliminating glazed papers; but they require for books a cheap and durable paper which will reproduce half-tones well; (2) paper manufacturers contend that they will produce a paper to meet the requirements of publishers when there is a demand for it; (3) school officials have given little or no attention to glazed surfaces. The committee has contemplated conducting, in conjunction with the research committee, an investigation of the question of glare from paper; it proposed the starting, at some future date, of a definite movement to eliminate polished surfaces wherever possible, particularly glazed paper from school books.

COMMITTEE ON RECIPROCAL RELATIONS WITH OTHER SOCIETIES

Co-operative relations with some thirty-two professional, scientific, commercial and philanthropic organizations were promoted during the year. Joint meetings were held with a number of others. "It is believed that through the work of the committee the society's name and influence have been materially advanced. The I. E. S. has been brought to the attention of various organizations, heretofore ignorant or indifferent to its existence. While in every case we have not met with the success we had hoped, we believe our work to be cumulative and, if properly followed up, will ultimately be productive of most profitable relations with all organizations interested in illumination." The report also contained suggestions for the next committee. The committee promoted co-operative relations with the following societies:

American Academy of Medicine.
American Association of Cotton Manufacturers (Boston, Mass.).
American Association of Cotton Manufacturers (Charlotte, N. C.).
American Electro-Therapeutic Association.
American Gas Institute.
American Institute of Architects.
American Institute of Mining Engineers.
American Ophthalmological Society.
American Medical Association.
American Public Health Association.
The American School Hygiene Association.
American Society of Mechanical Engineers.
American Association for Conservation of Vision.
Architects and Engineers Club.
Architectural Club of Washington.

Association of Edison Illuminating Companies.
Association of Iron and Steel Electrical Engineers.
Association of Railway Electrical Engineers.
Association of Railway Surgeons.
Association of Stationary Engineers.
Committee on the Prevention of blindness.
Industrial Safety Association.
Institute of Electrical Engineers.
Medical Society of the State of Illinois.
Medical Society of the State of New York.
Medical Society of the State of Pennsylvania.
Museum of Safety.
National Commercial Gas Association.
National Electric Light Association.
Ohio State Medical Association.
Physiological Society.

COMMITTEE ON PROGRESS

This report was supplementary to the report of the committee which is printed in the November issue of the TRANSACTIONS; it suggests that it would be desirable for the next progress committee to endeavor to base much of its report on a review of articles pertaining to illuminating engineering which may appear in the various domestic and foreign journals; in other words, a report should constitute as far as possible a conspectus of progress in illuminating engineering. The preparation of such a report, it was stated, would involve a vast amount of painstaking work in abstracting and indexing matter from many publications.

SECTION DEVELOPMENT COMMITTEE

During the year the committee held two meetings; recommended the appointment of section representatives on the national papers committee; undertook the preparation of a guide on section management; and suggested the appointment of representatives or local secretaries in cities not having sections; and in a general way sought to promote the welfare of the sections and the society. The appointment of a committee to organize a section comprising cities in the Lake Erie region was made as a result of a recommendation of the committee.

COMMITTEE ON NOMENCLATURE AND STANDARDS

The report appears in full in the December issue (1912) of the TRANSACTIONS; it gives a number of new photometric definitions and a brief account of the committee's activities.

COMMITTEE ON RESEARCH

The report stated that the committee hoped to be able to submit a report of accomplishments next year, if the council deems it advisable to continue the committee. The functions of the committee were outlined as follows: "It should be a sort of a clearing-house in illuminating engineering matters. It should endeavor to see that investigations which are necessary for application in practise are undertaken by those competent and prepared to do such work. It should be prepared to recommend to those desiring to undertake research work suitable problems to be investigated. It should bring into closer co-operation the various scientific and technical bodies and should keep in close touch with the various scientific and technical schools where research work in any of the allied sciences is undertaken."

COMMITTEE ON EDITING AND PUBLICATION

The TRANSACTIONS for 1912 had approximately 300 pages less than the

TRANSACTIONS of 1911, and the cost was about $1,100 less. Condensation and elimination accounted for practically all of both these reductions. Three recommendations were made: (1) the arrangement of the TRANSACTIONS into two parts—a news section and a section devoted entirely to papers, discussion and reports; (2) the use of a paper freer from glare than the paper in use; (3) the publication of a guide setting forth the requirements and general style of papers and discussion which would reduce printing expenses and facilitate the work of publication.

COMMITTEE ON ADVERTISING

The advertising revenue of 1912 was $1,356, as compared with $1,225 for 1911. Contracts obtained for additional space in the TRANSACTIONS together with those pending should net about $2,500 in 1913.

COMMITTEE ON NEW MEMBERSHIP

A quiet but conservative campaign was made for new members. Most of the 201 applications and 3 reinstatements during the year 1912 are attributable to the activities of the committees. The committee recommended that the next committee be made up of the chairmen of the section membership committees and such others as may be expedient in the conduct of the committee's work. If the committee will keep in close touch with the section membership committees and encourage an exchange of ideas or plans, it was said that its work will be greatly facilitated.

1912 CONVENTION COMMITTEE

This report was the last of a series of reports by the committee. It included a scrap book of samples of all the literature of the recent convention and a number of valuable suggestions as to procedure, which should be of use to future convention committees. A check for $177.74, the excess of receipts over expenditures by the committee, accompanied the report.

Council Notes.

JANUARY COUNCIL MEETING

Twenty-five applicants were elected to membership at a regular meeting of the council which was held in the general offices of the society, 29 West Thirty-ninth Street, New York, January 10, 1913. The names of those new members are listed on page 5. Twenty-nine resignations, most of which had been held over from the previous year, were accepted.

A series of amendments to the by-laws, most of which were necessitated by a recent constitutional change in the fiscal year of the society, was read for the first time.

Annual reports were received from the following committees: new membership, finance, nomenclature and standards, editing and publication, research, reciprocal relations with other societies, section development, glare from reflecting surfaces, progress, illumination primer, factory lighting legislation. A synopsis of each report is given elsewhere in this issue.

The final report of the 1912 convention committee was received.

President Lansingh reported progress in the work of organization of a Lake Erie section of the society.

Mr. W. R. Addicks, president of the American Gas Institute, invited the council to appoint a representative of the society to a committee which is to arrange for a gas congress in San Francisco during the Exposition in 1915.

The president was authorized to appoint this representative.

The 1912 annual report of the general secretary was received. This report with certain modifications was made the report of the council to the society; it appears in full elsewhere in this issue of the TRANSACTIONS.

Those present at the meeting were:

V. R. Lansingh, president; J. D. Israel, A. J. Marshall, P. W. Cobb, George S. Barrows, H. E. Ives, J. W. Cowles, R. C. Ware, W. J. Serrill, J. T. Maxwell, L. B. Marks, C. J. Russell, E. P. Hyde, C. H. Sharp, E. B. Rosa, A. E. Kennelly, C. O. Bond, Norman Macbeth, and Preston S Millar, general secretary. Mr. W. R. Addicks, president of the American Gas Institute, was present upon invitation.

SPECIAL COUNCIL MEETING

A special meeting of the council, the first meeting of the new administration, was held in the Engineers' Club, New York City, January 10, 1913. Those in attendance were:

Preston S. Millar, president; J. D. Israel, general secretary; C. J. Russell, George S. Barrows, C. H. Sharp, E. B. Rosa, W. J. Serrill, C. O. Bond, P. W. Cobb, R. C. Ware, L. B. Marks, E. P. Hyde, H. E. Ives, J. T. Maxwell, J. W. Cowles, Norman Macbeth, and V. R. Lansingh.

After a discussion of the question of sustaining membership, it was resolved that the dues of sustaining members be left to the discretion of the committee (committee to be appointed by the president) having this matter in charge, that the amount of such dues be not published in the by-laws, and that the rules and regulations which may be proposed by the committee be first approved by the council or its executive committee.

A list of changes in the by-laws, most of which were necessitated by the recent constitutional change in the fiscal year of the society, was read a second time and adopted.

President Millar announced his appointments to various standing and temporary committees. The appointments were approved. It was understood that additional appointments to these committees would be made later. A list of committees and the personnel of each appears in the front part of this issue of the TRANSACTIONS.

An appropriation of $100 was authorized to cover the cost of printing a prospectus on the society and its work.

The president was authorized to appoint a committee of five to investigate, and report to the February council meeting, the matter of appointing representatives or local secretaries in cities not having sections of the society.

It was decided to hold the regular meetings of the council during the present administration in the morning of the second Friday of each month—except, of course, during the months of July, August and September, when no regular meetings are held.

New Members.

At a meeting of the council held in New York, January 10, the following applicants were elected members of the society:

ARRIGHI, ROSWELL.
Agent, The New York Edison Company, 124 West 42nd Street, New York.

BAKER, CYRUS REXFORD.
Incandescent Lamp Specialist, General Electric Co., 30 Church Street, New York.

BIERMAN, CHAS.
Telephone Engineer, Wisconsin Telephone Co., 183 5th Street, Milwaukee, Wis.

BROWN, MELVIN P.
Lighting Inspector, Dept. Water Supply, Gas & Electricity, 13-21 Park Row, New York.

CAMPBELL, O. M.
Sales Engineer, National X-Ray Reflector Co., 235 W. Jackson Boulevard, Chicago, Ill.

COLE, CHAS. M.
Illuminating Engineer, Wheeler Reflector Co., 156 Pearl Street, Boston, Mass.

CONNER, GEORGE C.
Engineer, National Electric Lamp Association, 4411 Hough Avenue, N. E., Cleveland, Ohio.

DALTON, PARKER C.
Salesman, Philadelphia Electric Co., 1000 Chestnut Street, Philadelphia, Pa.

DUANE, DR. ALEXANDER.
129 East 37th Street, New York.

FERGUSON, JOSEPH SIMPSON.
Student, Philadelphia Trades School, 12th and Locust Streets, Philadelphia, Pa.

GALAVAN, EDWARD.
Sales Engineer, National X-Ray Reflector Co., 235 W. Jackson Boulevard, Chicago, Ill.

KEANE, H. P.
Sales Engineer, National X-Ray Reflector Co., 235 W. Jackson Boulevard, Chicago, Ill.

KNIGHT, J. HARMER.
Draftsman, Philadelphia Electric Co., 10th and Chestnut Streets, Philadelphia, Pa.

LA BELLE, JOHN N.
Supervising Engineer, National X-Ray Reflector Co., 235 W. Jackson Boulevard, Chicago, Ill.

LEWIS, DR. F. PARK.
454 Franklin Street, Buffalo, N. Y.

MARTIN, W. G.
Engineer, National X-Ray Reflector Co., 235 W. Jackson Boulevard, Chicago, Ill.

MASS, HERBERT C.
Illuminating Engineer, 436 Henry Bldg., Seattle, Wash.

MAXWELL, C. M.
Electrical Draughtsman, R. D. Kimball Co., 15 West 38th Street, New York.

MCKINNIE, E. C.
Engineer, National X-Ray Reflector Co., 235 W. Jackson Boulevard, Chicago, Ill.

PARROTT, ROBERT.
Sales Engineer, General Electric Co., 30 Church Street, New York.

SELLECK, JOHN K.
Engineer, National X-Ray Reflector Co., 235 W. Jackson Boulevard, Chicago, Ill.

SEYMOUR, F. W.
Lighting Inspector, Dept. Water Supply, Gas & Electricity, 13-21 Park Row, New York.

STATES, WILMER M.
Salesman, General Electric Co., Edison Lamp Works, Harrison, N. J.

SULLIVAN, J. B.
General Electric Company, Foreign Department, Sarmiento 531, Buenos Aires, Arg.

TOLMAN, W. H.
Director, Museum of Safety, 29 West 39th Street, New York.

Section Activities.

CHICAGO SECTION

A regular meeting of the Chicago section was held in the auditorium of the Western Society of Engineers, Chicago, January 15, 1913. Sixty-five

members and guests were present. Mr. T. H. Aldrich of the National X-Ray Reflector Company and Mr. J. P. Malia, chief electrician of Armour & Company, presented a paper entitled "Indirect Illumination of General Offices." The paper was for the most part a detailed description of the lighting installation in the general offices of Armour & Company.

The following program of meetings has been arranged:

February 22—A joint meeting of engineers, architects and ophthalmologists, several organizations participating, in Milwaukee, Wis.

March 19—Announcement will be made later.

NEW ENGLAND SECTION

A regular meeting of the New England section was held in the auditorium of the Edison Electric Illuminating Company, January 21, 1913. Two papers were read: one on "Commercial Lenses" by Dr. H. P. Gage of the Corning Glass Company, Corning, N. Y.; the other, "Problems of Lighthouse Service and How They Met" by Dr. Raymond Haskell of the United States Lighthouse Service. Both papers were illustrated by lantern slides and were very interesting. Preceding the meeting a dinner was held at "The Georgian," at which plans for the general welfare of the section were discussed.

The following program, subject to change, has been announced:

February 17—Joint meeting with the Boston section of the American Institute of Electrical Engineers. Papers: "Ornamental Magnetite Arc Lamps" by C. A. B. Halvorson of the General Electric Company, West Lynn, Mass.; "The Enclosed Flame Arc Lamp" by W. A. Darrah of the Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.; "Mercury-Vapor Lamps" by P. H. Thomas, New York.

March 18—A demonstration of interior lighting effects, by Preston S. Millar.

NEW YORK SECTION

The New York section held a joint meeting with the National Commercial Gas Association in the United Engineering Societies' Building, January 9, 1913. Two papers—"The Lighting of Taft Hall in the Auditorium Armory" (Atlanta, Ga.) by Robert F. Pierce of the Welsbach Company, and "The Lighting of the Exhibition Hall, Auditorium Armory" (Atlanta, Ga.), by J. M. Coles, were presented. About 175 attended the meeting. Preceding the meeting there was an informal dinner at Keene's Chop House.

The program of meetings for the remainder of the season is as follows:

February 7—A joint meeting with the Municipal Art Society at the New York Arts Club.

March 13—Joint meeting with the American Society of Mechanical Engineers in the United Engineering Societies Building, 29 West 39th Street, New York. Mr. Ward Harrison of the National Electric Lamp Association will present a paper on "Industrial Lighting."

April 8—This meeting will probably be held in the United Engineering Societies Building. Mr. M. Luckiesh of the National Electric Lamp Association will present a paper on "Light and Art." A paper on "Phosphorescence and Fluorescence" is also scheduled. This meeting should be an unusually interesting one.

May 8—A talk on theater lighting by Mr. Bassett Jones, Jr., at the Clymer Street Theater, Brooklyn. During the past year Mr. Jones has conducted a

great deal of experimental work in theater illumination particularly in the production of stage effects. The members of the New York chapter of the American Institute of Architects will be invited to attend this meeting. Admission will be by card.

June 8—It is planned to have a joint meeting and outing of all the engineering societies in New York.

PHILADELPHIA SECTION

A joint meeting with the Philadelphia section of the American Institute of Electrical Engineers and the Philadelphia Electric Company section of the National Electric Light Association was held at the Engineers' Club, 1317 Spruce St., Jan. 13. Short talks on the subject of "Modern Illumination" were given by Prof. George A. Hoadley of Swarthmore College, Prof. Arthur J. Rowland of Drexel Institute, and Joseph D. Israel of the Philadelphia Electric Company. Dr. G. S. Crampton, W. E. Robertson, H. Calvert, B. Frank Day, R. F. Pierce, and G. H. Swanfeld also gave brief talks on various phases of the subject of illumination Mr. R. B. Ely exhibited a number of modern illuminants.

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A number of members of the Philadelphia section attended the meeting of the Franklin Institute and the Philadelphia Electric Company section of the National Electric Light Association in the auditorium of the Institute, 15 South Seventh Street, Thursday evening, January 30. At that meeting Dr. E. P. Hyde presented a paper on "The Physical Laboratory of the National Electric Lamp Association." Dr. Hyde's paper was supplemented by a series of lantern slides showing the new buildings of the association which occupy a forty-acre plot in Cleveland, which is to be known as Nela Park. Dr. Hyde stated that when the buildings are completed there will be available excellent facilities for the conduct of the scientific problems of the lighting industry.

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The following meetings have been scheduled:

February 21—A demonstration of interior lighting effects by Preston S. Millar.

During the week of March 23 a meeting will be held in the New Century Drawing Rooms. Mr. M. Luckiesh of the physical laboratory of the National Electric Lamp Association will present a paper on "Light and Art." Notices of this meeting will be issued shortly.

The dates and papers for subsequent meetings will be announced later.

PITTSBURGH SECTION

Mr. H. W. Shalling read an interesting paper on "Department Store Lighting" at a meeting of the Pittsburgh section, January 24. The paper and its attending discussion appears in this issue of the TRANSACTIONS. The members in attendance were the guests of McCreery & Company, in whose store the meeting was held. At the conclusion of the meeting a resolution of thanks to McCreery & Company was adopted.

The program of meetings for the rest of the season is as follows:

February—"Gas Lighting" by S. B. Stewart.

March—"Moving Picture Lanterns from the Central Station Point of View" by J. F. Martin.

April—"Railroad Car Lighting" by J. L. Minick.

May—"Physiological Aspects of Illumination" by W. E. Reed.

June—Announcement will be made later.

Annual Meeting.

Sixty-nine members and guests were present at the annual meeting which was held in the Aldine Club, Fifth Avenue and 23rd Street, New York, January 10, 1913. A dinner preceded the meeting. Brief addresses on the society and various phases of its work were made by Dr. A. E. Kennelly of Harvard University, Mr. T. C. Martin, secretary of the National Electric Lamp Association, Dr. W. H. Tolman, director of the American Museum of Safety, Dr. C. H. Sharp of the Electrical Testing Laboratories, Mr. L. B. Marks, first president of the society, Mr. V. R. Lansingh, the retiring president; Mr. W. R. Addicks, president of the American Gas Institute, and Mr. J. W. Lieb, Jr., vice-president of the New York Edison Company.

During the meeting it was announced that the following officers had been elected at the previous election: Preston S. Millar, president; vice-presidents, Wm. J. Serrill, J. W. Cowles, J. R. Cravath, H. S. Evans; general secretary Joseph D. Israel; L. B. Marks, treasurer; and C. O. Bond, P. W. Cobb and W. Cullen Morris, directors. The announcements were received with applause. It was also reported that the constitutional amendments which had been submitted at the election had been adopted.

Retiring President Lansingh then introduced President Millar, who delivered his inaugural address on the progress and functions of the society. The address is printed elsewhere in this issue of the TRANSACTIONS. A brief address was also delivered by Mr. Joseph D. Israel, the newly elected general secretary.

The report of the council covering the work of past year was presented in an abstract form. The full report, the report of the general secretary, is printed in this number.

A New By-Law.

The following by-law which outlines the procedure of section nominating committees was adopted at a meeting of the council, January 10, 1913:

The procedure in nominating and electing section officers shall be as follows, except when other procedure shall be authorized by the Council.

A section nominating committee shall be appointed by the Section Board of Managers each year. The appointment shall be reported to the General Secretary. This committee shall consist of five members of whom at least two shall be past officers of the Section or members of the Council. Not later that March 15 of each year, the General Secretary shall notify the chairman of the committee that it is the committee's duty to prepare a nomination ticket containing the names of those whom they deem best suited for the section offices to be filled at the ensuing annual election. The report of the committee shall be prepared in duplicate, one copy shall be submitted to the chairman of the section and the other copy shall be delivered to the General Secretary not later than April 25. The ticket thus prepared by the committee on nomination shall be printed and forwarded to all section members not later than May 5, in connection with the ballots for election of general officers. The election of section officers in other respects shall be carried out in a manner similar to that prescribed for the election of general officers, save that a copy of the report of the Committee of Tellers on the results of the section election shall be mailed as soon as prepared, to the chairman of the section and to the chairman-elect.

This by-law will standardize and facilitate the procedure in electing section officers. It will also eliminate considerable work and expense in connection with the elections.

Annual Report of the Finance Committee for the Fiscal Year 1912.

To the Council of the Illuminating Engineering Society:

In accordance with the provisions of the constitution of the society, the Finance Committee exercised direct supervision over the financial affairs of the society.

The committee held a meeting each month except during July, August and September, examined and approved all bills paid by the society, and presented a written report at each meeting of the council.

The financial condition of the society as of Dec. 31, 1912, is given in the subjoined statement of Messrs. William J. Struss & Co., certified public accountants, who were employed by authorization of the council to audit the books and accounts of the society.

The auditor's report shows a deficit of $640.07 for the year and an impairment of surplus amounting to $1,435.63 since Jan. 1, 1912.

The membership of the society at the close of the year was 1,325. At one time during the year the membership reached 1,470. Based on an average active membership of 1,350 for the year, the expenses per member were $7.36. The income, other than that obtained from membership dues, was derived chiefly from the proceeds of advertising and miscellaneous sales of the TRANSACTIONS of the society.

Early in 1912 the committee reported to the council that the society was likely to face a considerable deficit at the close of the year, and recommended that immediate steps be taken to secure a larger income from the membership. The council appointed a special committee on "Financial Policy" and subsequently a committee on "Revenue," to consider ways and means of placing the society on a sound financial basis and, as a result of protracted discussion of the subject, the plan of "Sustaining Membership" (now forming part of the constitution) was finally evolved. If this plan works out as well as expected, the income derived from the membership at large will be sufficient not only to defray the ordinary running expenses of the society, but also to meet increased expenses due to expansion of the activities of the society.

Respectfully submitted,

A. A. POPE,
A. S. MCALLISTER,
L. B. MARKS, *Chairman.*

STATEMENT OF THE AUDITORS.

Exhibit "A."—Balance Sheet, December 31, 1912.

ASSETS.

Cash—		
On hand and in bank		$1,918.23
1913—New York Section expenses paid 1912		29.25
Accounts Receivable—		
1912 dues	$ 12.50	
Miscellaneous accounts	510.01	
Initiation fees	10.00	
1912 advertising	402.38	
Total		934.89
Property Accounts—		
Furniture and fixtures	630.21	
Less depreciation—15 per cent.	94.53	
Net	535.68	
Badges on hand (29)	84.00	
Total		619.68
Investments—		
Northern Pacific and Great Northern Railway Bonds—$2,000		1,920.00
Total		$5,422.05

LIABILITIES.

Accounts payable	$ 803.57
Advance dues	2,060.00
Advance fees	5.00
December expenses estimated—Exhibit "B," Schedule No. 1	1,080.00
Advance advertising	19.54
Surplus—Exhibit "A," Schedule No. 1	1,453.94
Total	$5,422.05

Exhibit "A," Schedule No. 1—Surplus Account, Dec. 31, 1912.

Surplus—January 1, 1912	$2,889.57
Duplicate charge in 1911	9.98
Back dues	10.00
	2,909.55

1911 New York Section expenses	$ 62.10	
1911 General Office	60.30	
1911 TRANSACTIONS	287.66	
1911 Philadelphia Section expenses	28.85	
1911 Chicago Section expenses	56.49	
Dropped (various) in default of fees	74.00	
1911 Election expenses (part)	163.85	
1911 Membership Committee (part)	82.29	
Deficit for year 1912 (see Exhibit "B")	640.07	
		1,455.61
		$1,453.94

EXHIBIT "B"—STATEMENT OF EARNINGS AND EXPENSES FOR THE YEAR ENDED DECEMBER 31, 1912.

EARNINGS.

Members' dues	$6,872.19	
Advertising	1,356.22	
Miscellaneous sales of TRANSACTIONS	586.78	
Initiation fees	375.00	
Interest on bonds	80.00	
Profit on badges sold	21.00	
Members' certificates	8.00	
Total		$9,299.19

EXPENSES.

TRANSACTIONS	$2,253.29	
December expenses estimated (Exhibit "B"—Schedule No. 1)	1,080.00	
General Office (Exhibit "B"—Schedule No. 2)	4,057.34	
New York Section	389.83	
Chicago Section	251.17	
New England Section	208.43	
Pittsburgh Section	148.31	
Philadelphia Section	291.32	
Committee on Illumination Primer	463.15	
1912 Convention Committee	420.14	
1912 Election expense	114.12	
Depreciation—furniture and fixtures	94.53	
Papers Committee	44.07	
Committee on Reciprocal Relations	4.25	
Committee on Nomenclature and Standards	15.70	
Joint meetings with other societies	27.43	
Annual Meeting	32.75	
Authors' advance copies	5.38	
Treasurer's expense	16.44	
President's expense	9.25	
Exchange on checks	12.36	
Total		9,939.26
Excess of Expenses over Earnings		$640.07

Exhibit "B," Schedule No. 1—December (1912) Expenses, Estimated.

Primer	$680.00
Transactions	250.00
Chicago Section	10.00
Philadelphia Section	20.00
Pittsburgh Section	5.00
New England Section	5.00
General Office (part)	50.00
Miscellaneous	60.00
	$1,080.00

Exhibit "B," Schedule No. 2—Analysis of General Office Account for the 12 Months Ended Dec. 31, 1912.

Salaries: Assistant Secretary and Stenographer	$2,210.68
Rent	666.00
Postage	298.57
Telephone and telegraph	152.98
Printing, stationery, etc.	332.37
Miscellaneous	396.74
	$4,057.34

TRANSACTIONS

OF THE

Illuminating Engineering Society

JANUARY, 1913

PART II

Papers, Discussions and Reports

[JANUARY, 1913]

CONTENTS -- PART II

INAUGURAL ADDRESS OF PRESIDENT MILLAR.*

Fellow Members of the Illuminating Engineering Society:

We who are members feel sure that this society is destined to fulfill an important purpose. The problem which it must solve is tremendously difficult and almost unique in its complexity. The goal has been pointed out and described by Past-President Hyde in these words:

> The goal of illuminating engineering will have been attained when as a result of the concomitant development of its component elements, it will be possible in every case presented, to design a lighting installation which will be efficient, effective, artistic; which will produce an illumination correct in quantity and quality properly balanced as to high-light and shadow, restful to the eye and harmonious with the form and color schemes involved; which will stand the rigorous test of logical analysis, and will appeal to the highly developed sense of beauty. The goal of illuminating engineering is the attainment to the ideal application of perfect knowledge.

At the time when the society was organized we were far from the goal. Many of us did not know what or where the goal is. Our lighting practise in general was execrable. To-day we are well started on our way. While the goal is still so far away that we cannot afford to interrupt our journey to celebrate progress, yet we may pause a moment to look backward and contemplate with gratification the improvement which has taken place in lighting practise and the advance made in our knowledge of lighting principles. From such contemplation we may derive inspiration for the great journey still before us.

The history of the society covers seven years. They have been busy years. Much has been accomplished though that much seems little when compared with the great work remaining to be accomplished.

The first year was devoted to establishing the society, bringing into its membership those connected with various industries and professions concerned, and securing papers on some of the many aspects of the subject of lighting, in order to introduce the society and start it on its way. Through the Herculean efforts of President Marks the year closed with more than 800 members, surely a phenomenal record.

* Delivered at the annual meeting of the Illuminating Engineering Society, New York, January 10, 1913.

The second year, Dr. Sharp's administration, was devoted to the establishment of sections, the extension of the society's influence throughout various cities and the perfection of its organization. Many vexing problems of an intra-society character were met and disposed of. The foundation was laid for the society's later work.

In the third year, Dr. Bell's administration, the society may be said to have found itself as an organization. The various officers attended to their functions and a display of team work made it evident that this is no one-man enterprise, but a well organized society with many actively interested members.

During the fourth year, under the administration of President Gartley, internal affairs were further strengthened and the purpose and work of the society was brought before the gas industry in a way to enlist more support than had ever before been accorded.

In the fifth year our organization was found to be strong enough to attempt something beyond the continued development of its internal activities and the lecture course on illuminating engineering was conceived by Dr. Hyde and carried through with notable success. Thus was the scope of illuminating engineering defined, a clearer conception of its various elements placed before the society and the public, and the ground-work laid for university educational courses in illumination.

The sixth year witnessed an extension of work to include the education of the public in lighting fundamentals. Work was started upon a primer of illumination. At the same time another step was taken toward the establishment of the profession of illuminating engineering through Dr. Kennelly's scholarly inaugural address.

During President Lansingh's administration the illumination primer has been completed and its dissemination begun. The society has given additional evidence of realization of responsibility to humanity by the appointment of a Committee on Glare from Reflecting Surfaces. It has sought to discharge its civic duty through the activity of a Committee on Factory Lighting Legislation which has co-operated with the New York State Labor Commission in devising constructive but safe and sane legislation on industrial illumination.

Thus we find that the first four years of the society's work were devoted to perfecting its organization, improving its internal mechanism, and developing its function as a forum for discussion. With the fifth year came activity looking toward the creation of a profession of illuminating engineering. This was followed quickly by efforts toward public education. A perfectly logical course of action, involving first preparation for the task, and after at least some material progress has been made within the society as preparation, the application outside the society of the knowledge acquired in an effort to benefit the public and establish the profession.

As I see it therefore we have arrived at a stage of development where our functions are defined not alone by declaration but by actions as well. These functions are three in number.

First, to serve as a forum for the presentation and discussion of technical questions pertaining to light and illumination, thereby promoting the advance of knowledge and informing the membership of knowledge acquired;

Second, to improve lighting practise through the formulation and application of principles of good illumination and through the education of lighting practitioners and the public at large in matters of illumination;

Third, ultimately, perhaps, to establish a professional basis for illuminating engineering.

In regard to the third function, I believe that we are all in accord in a desire to promote developments which will contribute toward the establishment of a professional basis for illuminating engineering; but it does not appear to me that the time is ripe for determined effort in that direction. I believe that without neglecting this aspect of our problem we may direct our greatest energies more profitably toward accomplishment in other directions. Give education, that great panacea, some further opportunity to create the demand; advance the boundaries of knowledge of illumination; devote efforts to earning greatest respect for the society; and all in good time the need for such a specialty will be generally recognized and it will be found practicable to establish the desired professional basis.

As a forum, the society is concerned with the *science* of

illumination. Knowledge must precede application. It was inevitable therefore that this part of the work should have featured the earlier years. Thus the mathematics of illumination, well grounded by Dr. Sharp in his presidential address in 1907, has been thoroughly developed and has received a full share of attention in our deliberations. The measuremnet of light as an element of fundamental importance has been widely discussed, though much remains for future development. Papers presenting experience of lighting practitioners have naturally predominated and in the aggregate have added much to our store of knowledge. These are among the many phases of the science of illumination which have received treatment commensurate with their importance. But there are some phases which, contrary to the desire and in spite of the effort of the successive administrations, have not been adequately discussed. Among these are the principles of architecture and decoration as constituting requirements for lighting design. Our science is deficient in this respect, and there is no more important need to be met than the supply of knowledge to meet this deficiency.

The *art* of illumination, in the sense of application of knowledge, has been developed rapidly with the advancement of the science. Newly designed installations, and new lighting equipments are greatly in advance of those of eight years ago. But the many installations which transgress principles of hygiene, esthetics or economy are every-day evidence that relatively little has been accomplished. And the remedy for this we believe is education—education of our members and others who have to do with the installation of lighting equipment; education of members of organizations who may become interested in improving lighting conditions; education of students in our universities and schools; education of the public at large. Many of us find ourselves peculiarly sensitive to untoward effects of bad lighting because we have studied illumination and recognize bad conditions to which we formerly were unconscious. Our problem is to educate the American people to be similarly impressed by bad lighting. When that is done most of the very bad lighting will be improved. To succeed, the society must address itself to the task of furthering this educational work upon which such an excellent start has been made.

The society this year is committed to a policy of expansion. We are to seek to extend our influence in a number of ways.

The establishment of local representatives in cities where there is no section is expected to result in a more general knowledge of our purpose and work, and to promote the application of principles of good lighting. In arousing and maintaining local interest in lighting matters, this is expected to extend greatly the society's influence for good.

Sustaining membership provides a means whereby lighting companies, manufacturers and others who recognize the value of the society's work to them may give a limited amount of support in application of that work. Of equal importance, it gives the society an opportunity and an incentive to convince other companies of the actual or potential value of its work and of the importance of supporting it.

To sum up, it is my view that the society's greatest needs at the moment are:

1. Increased knowledge of the architectural and decorative requirements in illumination design.

2. Extension of educational work in its various forms.

3. Successful application of new constitutional provisions for expanding the influence of the society.

To make some progress along each line is the purpose of the administration. If material accomplishment is to result, there must be a continuance of the active loyal support of officers, committees and members, which has made possible the developments of the past seven years. Upon obtaining such support I feel that we may rely with confidence. For the rest, "it is not in mortals to command success"—but we will do more, we will deserve it. And paraphrasing the Father of our Country we may say, "Let us raise a standard to which all who are sincerely interested can repair. The event is in the hands of God."

1912 REPORT OF THE GENERAL SECRETARY.

Nineteen hundred and twelve, the seventh year of the society's history, was notable chiefly for a quiet persistent improvement in internal affairs and a general extension of the society's work along educational and co-operative lines. The following brief review of the year's activities records the salient features.

TECHNICAL AFFAIRS

Transactions.—While there is some difference in the distribution of papers in the TRANSACTIONS, yet the total number (40) is so small as to make it impracticable to observe any trend in the character of the deliberations. A growing tendency on the part of the Committee on Papers to refrain from printing papers of doubtful permanent value has reduced the volume of the TRANSACTIONS and increased the number of unrecorded lec-

CLASSIFICATION OF PAPERS IN FIRST SEVEN VOLUMES OF THE TRANSACTIONS

Subject of Papers		No. of Papers
Light		21
Physics	8	
Color	5	
General	1	
Reflection coefficients	7	
Illuminants		37
Electric	14	
Gas	20	
Miscellaneous	3	
Lighting Auxiliaries		10
Illumination		118
Principles	50	
Artificial: Interiors	48	
Exteriors	16	
Natural Outdoors	2	
Indoors	2	
Units, Standards and Calculations		31
Photometry		26
Illuminating Engineering		16
Miscellaneous		6
Total		265

Of a nature to interest particularly	No. of Papers
Architects	42
Decorators	29
Fixture Manufacturers	28
Ophthalmologists	27
Manufacturers of Illuminants	61
Manufacturers of Lighting Auxiliaries	61
Lighting companies	55
Illuminating engineers	222
Scientists	87

tures or papers which have been presented before section meetings.

As during the previous year, discussions of papers have often been inadequate. It appears advisable to foster more general discussions of papers, this being the best safeguard against inaccuracies which are likely to creep into papers in spite of the best precautions of authors, and papers and editing committees. Further emphasis upon advance printing of papers and upon general discussions, whether written or oral, is therefore in order.

The addition of Volume VII to the TRANSACTIONS makes the aggregate number of papers which have been presented before the society 265. These are distributed as to character and scope substantially as indicated in the accompanying table.

CONVENTION.

One of the best evidences of increasing strength of the society is offered by successive annual conventions, each one of which makes a more impressive showing than the last. The convention of 1912 is recorded as being eminently successful. The papers compared favorably with those of previous conventions in number and quality; the maintained attendance at the sessions was extraordinarily large in comparison with the registration, and evidenced keen interest in the proceedings. The spirit manifested toward the society's enterprise was all that could be desired.

SECTIONS

The condition of the established sections is substantially the same as at the beginning of the year. The Philadelphia and New York Sections are relatively strong in interest and attendance at meetings; the Chicago Section is giving evidence of better maintained interest than formerly. The New England Section continues in need of further development. The new Pittsburgh Section has been eminently successful during its first year. Its addition strengthens the Society. Its potentialities for the future seem good.

A proposal to establish a new section at Cleveland has been considered during the year with adverse conclusions. Out of it has grown a proposal to form a so-called Middle West or Lake Erie Section to comprehend the large cities, including Buffalo on

the east, Detroit on the west and Pittsburgh on the south, meetings to be held from time to time in the various large cities of that territory. This matter is still under consideration, although it has made a favorable appeal in Cleveland and Pittsburgh. If such a section is organized in the near future, its effect upon the Pittsburgh Section will remain to be determined.

The statistics for section meetings are as follows:

Section	Number of meetings	Papers presented
Chicago	8	7
New England	6	5
New York	9	7
Philadelphia	8	9
Pittsburgh	5	7
Totals	36	35

COMMITTEES

One of the Society's greatest elements of strength is its committees, which with few exceptions are gratifyingly active in the performance of their several duties. Approximately 75 members are devoting time and effort to the work of the general committees, and others are serving upon section committees. The Society may well be proud of its committee work. The officers and members of the Council hold in high appreciation the services which are rendered to the society and to the cause through such contributions.

Committee on Papers.—Provision of papers for the annual convention, and acceptance or rejection of all papers and discussions are the chief functions of this committee. The splendid convention papers program attests the excellence of its work during 1912.

Committee on Editing and Publication.—The routine work for which this committee is responsible has been performed during the year by the Assistant Secretary who under the supervision of this Committee and of the Committee on Papers acts as editor of the TRANSACTIONS. Editorial policies and questions of printing and distributing the TRANSACTIONS are the chief immediate responsibility of the committee.

Committee on Section Development.—This committee has directed its efforts toward the improvement and standardization

of section management methods and the extension of the Society's influence beyond the territory in which the Society is at present represented.

Committee on New Membership.—A new method of organization, calculated to co-ordinate the general and section new membership work, was tried by this committee during the year. Due to the fact that section terms of office expire in June, while the general society terms expire in January, the work of this committee has suffered somewhat from changing personnel. However, a steady, quiet pressure has been exerted, which has brought into the Society more than 150 men who are thought to be seriously interested in the work and who should be real assets for the future.

Committee on Reciprocal Relations with Other Societies.—This committee has communicated with various organizations during the year, suggesting co-operation through joint meetings, exchange of representatives on illumination committees, etc. The committee has been very effective in attaining its object, and much of the effort, incomplete at this time, is expected to bear fruit during the coming year. The lack of a suitable Society conspectus has made the committee's labors unnecessarily arduous and has reduced their effectiveness somewhat. The notable achievements of the year may therefore be taken as an indication of larger accomplishment in the future when better facilities shall be available for the committee's work.

Committee on Nomenclature and Standards.—This, the sixth year of the committee's existence, has been its most active year. The work of defining photometrical quantities has been continued, and much of our photometrical and lighting terminology which was in need of standardization has been reported upon during the year.

In addition to this work, the committee continued its effort, undertaken two years ago, to foster international co-operation in standardization of terminology and units. Its tentative proposal that an international commission be appointed to deal with such matters met with some opposition abroad on the ground that the International Photometric Commission (Zurich Commission) provides a means for effecting international standardization. A

plan is being developed for expanding the scope of this Commission and making it thoroughly representative in every respect. The committee has decided that if the reorganized commission fulfills the requirements, no better auspices could be obtained for international standardization and the most desirable course would be to await such reorganization and stand prepared to co-operate to the fullest possible extent in the international work which would then become possible. Pending the consummation of this plan, all international endeavor along lines of standardization is being held in abeyance.

Committee on Research.—Uncompleted committee organization and the lack of problems demanding immediate attention have resulted in a year of little activity for this committee. Considerable attention has been given to consideration of the scope, functions and personnel of the committee, and a preliminary step was taken by the chairman in laying down the principles of research in a paper at the Niagara Falls convention.

Committee on Progress.—This committee discharged its principal function in presenting at the annual convention a report on progress in the field of illumination.

Committee on Glare from Reflecting Surfaces.—Considerable work in the way of study of its problem has been undertaken by the committee, but in the few months elapsing since its appointment, it has been impracticable to carry much of the work to a conclusion. The end of the year finds the committee actively engaged in the promotion of its work, making reappointment of the present committee an essential in order that the effectiveness of its operation may not be interferred with.

Committee on Symbols.—This committee was appointed with a view to ascertaining whether or not there exists a need which it would be desirable for the Illuminating Engineering Society to meet by securing co-operation of various organizations, in an effort to standardize drafting symbols. While the committee's final report is not yet available, it appears that the need exists, but there is considerable doubt if the Illuminating Engineering Society is the organization which should take the lead in an endeavor to meet it.

Committee on Illumination Primer.—The illumination primer, completed during the summer, has been distributed very generally among the lighting fraternity, and those whose vocations are such as to establish a demand for knowledge of matters of illumination. Much remains to be accomplished however, in the way of popular dissemination. The primer has been received with encomiums all over the country and abroad. It is expected that its influence will be felt in the years to come both through awakened popular interest in matters of illumination and through added interest in the society's work.

Committee on Factory Lighting Legislation.—The work of this committee represents the society's first step toward the performance of a civic duty. Undoubtedly the New York State legislation on factory lighting will be the better for the influence which the committee has brought to bear on behalf of the Society.

Committee on Finance.—The financial condition of the Society is considered and all payments are approved at monthly meetings of this committee; also any financial problems which the Council may refer to it are discussed and reported upon. Due to the unsatisfactory condition of the society's finances, this committee has been called upon to devote more than usual thought and time to the discharge of its duties during the past year.

Committee on Advertising.—It has been the desire of the Council to decrease advertising in the TRANSACTIONS. An impending deficit this year led to a temporary departure from that policy and the committee responded in a very gratifying manner, securing advertising contracts which now yield a monthly revenue about 75 per cent. greater than that obtained at the beginning of the year.

Council Executive Committee.—This committee conducted the affairs of the society in the interims between council meetings especially during the summer period.

Board of Examiners.—This board is depended upon to consider and report on applications from territories other than that which falls under section jurisdiction, and to report to the Council upon any other applications which may be referred to it for consideration.

Committees on Financial Policy and Revenue.—These committees have considered the financial problem of the society and have reported to the Council upon ways and means of meeting the situation.

Convention Committee.—The notable success achieved by the convention was due in no small part to the excellent work of this committee. Technical, social and financial details were handled in an expert manner without calling upon the society for financial assistance other than the costs involved in recording and printing the proceedings. The committee financed the convention and turned over to the society a small surplus.

Committee on Tellers.—Appointed to count and report upon the vote of the membership in election of officers and on constitutional amendments, this committee discharged its duties with promptness and thoroughness.

Committee on Annual Meeting.—Arrangements for the annual meeting as well as for the dinner which preceded it were entrusted entirely to this committee with very pleasing results.

BUSINESS AFFAIRS.

It is difficult to make a brief, general statement of the society's financial condition because of accounting difficulties which render unqualified comparison with other years impracticable. A reduction in surplus from approximately $2,900 in January, 1912 to approximately $1,450 in January, 1913 shows a decrease of about $1,450 in surplus as a result of the year's operation. However, all December 1912 expenses have been included in the 1912 statement whereas about $800 of the 1911 expenses appeared in the 1912 statement. With this amount deducted from the surplus decrease, there remains an actual deficit of about $650 for 1912.

It is perhaps not ungratifying to report this deficit. To have reported an increase in surplus for the year would have been possible only as the result of a degree of stagnation of society affairs. Some of the new activities which commended themselves to the Council were undertaken in the face of an assured deficit because they were considered well worth while notwithstanding the unfavorable financial aspect. The inadequacy of members' dues to meet the ordinary expenses has been recognized by the Council and reported to the membership during the past few

years. The deliberate sense of the Council has been that since the society's enterprises were worthy of support, they should be carried out and increased support should be obtained, instead of curtailing enterprise to the point where the support already available would prove adequate.

The year's expenses include approximately $1,000 involved in the production and dissemination of the illumination primer. If it shall be found feasible to arrange for the extensive dissemination of the primer on terms which will make it possible for the society to reimburse itself for this $1,000 expenditure, the year's operations may be recorded as showing a profit rather than a loss.

MEMBERSHIP.

There has been some reduction in the number of members during the year, the defections being larger than the additions to the roll. The statistics are as follows:

Members January 1, 1912	1,418
Additions during year	206
Defections during year	289
Membership December 31, 1912	1,335

Seven members have been removed from us by death. Their names are:

George, Thomas L.
General Superintendent, The United Gas Improvement Co., Broad and Arch Streets, Philadelphia, Pa.

Manning, Wm. J.
District Manager, Philadelphia Electric Co., Gray's Ferry Road and Carpenter Street, Philadelphia, Pa.

Mayer, Frederick J.
General Manager, Didier March Co., 30 Church Street, New York, N. Y.

McGlensey, J. F.
Illuminating Engineer, Union Electric Light & Power Co., 12th and Locust Streets, St. Louis, Mo.

Morgan, A. J.
Secretary, National X-Ray Reflector Co., 235 W. Jackson Boulevard, Chicago, Ill.

Riblet, A.
Superintendent, 14th Street Station, Consolidated Gas Co., 14th Street and Avenue C, New York, N. Y.

Spillman, A. J.
Chief of Lamp Dept., Philadelphia Electric Co., 1000 Chestnut Street, Philadelphia, Pa.

ILLUMINATING ENGINEERING SOCIETY MEMBERSHIP—JANUARY 7, 1913

Class	Chicago	Foreign	New England	New York	Philadelphia	Pittsburgh	Scattering	Total	In per cent. of total
Architects	2	—	1	3	2	1	1	10	0.8
Decorators	—	—	—	2	—	—	—	2	0.2
Fixture Manufacturers	5	1	1	6	3	1	1	18	1.3
Contractors and Jobbers	16	3	3	21	12	3	2	60	4.5
Pedagogues	15	3	10	16	7	10	11	72	5.4
Ophthalmologists	3	1	2	3	1	2	1	13	1.0
Testing and Research	1	—	—	10	9	2	—	22	1.7
Illuminating Engineers—Consulting	2	1	1	3	—	—	1	8	0.6
" " with Mfg. Organ.	2	—	—	5	1	1	—	9	0.7
" " with Ltg. Cos.	1	1	—	3	2	—	1	8	0.6
Electric Lighting	36	9	13	46	122	11	25	262	19.6
Gas Lighting	21	2	18	57	85	2	14	199	14.9
Electric and Gas Lighting	12	—	5	30	11	—	16	74	5.5
Electric Lamp Manufacturing	21	7	13	58	13	63	11	186	13.9
Gas Lamp Manufacturing	2	1	2	12	18	2	—	37	2.8
Manufacturing of glassware, etc.	23	7	7	35	8	28	4	112	8.4
Consulting Engineers—Electrical	9	2	5	33	4	2	—	55	4.1
" " Gas	—	1	—	3	1	—	—	5	0.4
Electric Lighting other than Public	18	1	4	8	13	9	6	59	4.4
Technical Journals	5	2	—	12	1	—	—	20	1.5
Municipal and P. S. C. Engineers	3	2	1	11	8	1	2	28	2.1
Miscellaneous Illumination	—	—	—	3	2	1	—	6	0.4
Unclassified	13	7	7	15	16	7	5	70	5.2
Totals	210	51	93	395	339	146	101	1335	100.00
In per cent. of total	15.7	3.8	7.0	29.6	25.4	10.9	7.6	100	

The membership record is involved by the fact that bills for 1913 dues were issued early in December and resulted in a number of resignations which otherwise would not have been received until January. Resignations are always to be expected when bills for dues are issued. In this 1912 record, the defections include such resignations for the beginning and the end of the year, while in other years they include such resignations only for the beginning of the year. Corrected for this irregularity, the membership is found to have about held its own.

An approximate classification of the members by vocation appears in the preceding table. Such a classification is difficult and liable to unavoidable error so that the distribution should be considered no more than indicative.

GENERAL OFFICE.

The last annual report noted the inadequacy of office facilities in the United Engineering Societies Building, New York. During the past year an adjoining room has been secured which is now used as a business office, while the original room serves as the private office of the Assistant Secretary for editorial and other work, and for the meeting room of the Council, various committees, and the New York Section Board of Managers.

FOREIGN RELATIONS.

Abroad the year has been signalized by the announcement of the formation of a German Illuminating Engineering Society (Deutsche Beleuchtungstechnische Gesellschaft). Anticipating that the organization of this Society will be perfected during the coming year, it may be expected that the three societies located in respectively the United States, England and Germany, will find many points of common interest and much that is mutually beneficial in their activities. With the probability that the reorganized International Photometric Commission will meet the requirements of international standardization, there remain for development methods of co-operation in other matters among the various societies. The Illuminating Engineering Society through its Council stands ready to co-operate to the fullest extent with the English and German societies through their governing boards.

GENERAL.

The year's experience has indicated some lack in internal organization. Primarily this will be met if there can be established closer co-operation among the sections and between the sections and the Council. In this latter work the respective Vice-Presidents can be very influential. Among the committees there has been evidenced a need for better organization. Most committees need to hold at least occasional meetings, if the committee's organization is to be perfected and its plans definitely formulated. With these two general exceptions the organization of the society appears to be satisfactory.

The opportunities for effective service loom large for the future. Provisions for making available additional funds with which to carry out the work of the society should remove the only serious handicap under which we have labored in the recent past. The proven loyalty of large numbers of members gives assurance of means of accomplishment. All things considered, there is every reason to look for further growth and extension of influence in the near future.

PRESTON S. MILLAR,
General Secretary.

DEPARTMENT STORE LIGHTING.*

BY H. W. SHALLING.

Synopsis:—This paper, while it is for the most part confined to the re-designing of a particular lighting installation, outlines the problem usually encountered in the lighting of large department stores. Lighting systems, the relative advantages of direct and indirect lighting, uniformity of illumination, color of light, avoidance of objectionable shadows, maintenance, etc., questions which demand consideration in problems of this sort are discussed briefly. Generally, the re-designing in this case consisted of the substitution of tungsten lamp units for an existing installation of electric arc and carbon incandescent lamps. Both the old and the new installations are described in detail. Photometric data, results of illumination tests made on several floors, diagrams of the test stations and photographs of the two installations are also included. The installation changes described have afforded a lighting system which is not only more artistic and effective, but one that has reduced the operating costs of the old system more than fifty per cent.

The choice between different systems and different lighting units is generally made on the basis of, (1) relative efficiency; (2) relative attractiveness in appearance. These are the fundamental considerations, although there are others which are also of vital importance.

LIGHTING SYSTEMS.

All lighting systems can in general be classed under one of three classifications, viz., direct, indirect, and semi-indirect.

In practically all lighting systems some portion of the illumination is received indirectly. In other words a portion of the illumination is obtained by light reflected from the ceiling or walls, or both, before reaching the plane of utilization. In direct lighting when efficiency is important, it is the aim in general to make the indirect portion of the illumination small, allowing only enough light to reach the ceiling and walls to illuminate them to a low intensity, thereby preventing a gloomy appearance.

Indirect illumination is produced by the light coming from a very large area—the ceiling and upper portion of walls. This

* A paper read before a meeting of the Pittsburgh section of the Illuminating Engineering Society, January 24, 1913.

gives what is known as diffuseness of illumination. In such a system no direct light is received on the plane of utilization, the light source being concealed in an opaque unit.

What has been said in regard to indirect lighting applies equally well to semi-indirect lighting with this exception, viz., that the light source is mounted in a translucent rather than an opaque unit so that some of the illumination is received directly. When properly designed, a semi-indirect system possesses all the illumination advantages of totally indirect lighting. In addition, it is more attractive in appearance and avoids the unpleasant effect of a brilliant ceiling with no visible source of light. The great danger in the use of semi-indirect lighting is that the translucent units used will transmit too much light. When too much light is transmitted, the efficiency is very rarely any greater than with totally indirect lighting, and the illumination advantages of the indirect illumination are greatly reduced.

Experience has shown that the best degree of transmission of light with semi-indirect lighting units is possible when the brilliancy of the light unit is approximately the same as the brilliancy of the ceiling.

INDIRECT COMPARED WITH DIRECT LIGHTING.

Obtaining a large portion of the illumination indirectly has the following disadvantages as compared with direct lighting.

(1) Lower efficiency; to produce a given illumination requires about twice as much light with indirect lighting as with efficient direct lighting.

(2) More rapid deterioration due to the collection of dirt.

(3) A lower degree of perspective, since sharp shadows are largely eliminated.

(4) An unduly bright ceiling which often gives an unpleasant psychological effect, especially when the opaque unit of the indirect lighting forms a contrast with the brightly lighted ceiling.

For the reasons cited above, and since in the average department store a comparatively large area must be illuminated, it would seem that in most cases the general illumination can be obtained more economically, efficiently, and with units which will be sufficiently attractive in appearance, by a system of direct illumination.

Moreover, it is generally considered by most authorities that the advertising value or attractive power of a direct is far greater than that of an indirect system. It is not meant by this, however, that exposed light sources should be used for this purpose, but either totally enclosing units or reflectors which practically conceal the light sources in the case of incandescent electric lights. It is not the purpose of a department store to install lighting fixtures for display, except in those spaces as may be devoted to the sale of such goods. The light units should not attract attention from the goods displayed; the object should be to provide proper illumination for the display of goods at a reasonable expense to the owner; the fixtures, of course, should be sufficiently artistic in appearance and of a character which will be in harmony with the architectural surroundings.

IMPORTANT CONSIDERATIONS INVOLVED.

Color Value.—The light units employed should give light which in color approaches as near as possible that of natural daylight, so as not to distort the colors of the goods displayed. But there are certain classes of goods which will be used almost entirely under artificial light such as is found in the home, theatre, and similar places; the light under which these goods are sold should approximate that under which goods will be used, which is in general the incandescent electric lamp.

Due to its high efficiency, the possibility of a more efficient utilization of its light by the use of properly designed reflectors, ease of maintenance, and the range in sizes available, the tungsten filament lamp has gradually displaced the arc lamp for department store lighting. While tungsten lamps do not give the same color values as are given by daylight, the approximation is close enough for most practical purposes. For particular cases, special arc and incandescent units, which give a closer approximation to daylight values, have been developed and are continually being improved. At the present time, however, they are being used in specially prepared spaces and not for general purposes.

Avoidance of High Intrinsic Brilliancy.—The avoidance of glare from exposed brilliant sources is essential. If enclosing opal or prismatic glassware be used, this effect is reduced practically to a minimum. If prismatic or opal reflectors are used

they should be of a deep bowl shape so as to completely screen the lamp filament from the eye in all its normal positions. It is advisable also that the lower portion of the bowl of the lamp be etched or frosted.

Uniformity of Illumination.—The light units should afford such distribution of light as will produce a reasonable degree of uniformity of illumination; glassware which will effect the most desirable distribution of the light from the particular lamps, or for any particular arrangement of outlets or class of lighting service should be selected with care.

Avoidance of Objectionable Shadows.—It is highly important to avoid objectionable shadows cast by a customer in standing before a counter. For this reason careful attention should be paid to the arrangement of light units and their mounting heights.

Efficiency.—Efficiency is here used in the sense of illuminating efficiency. The reflector type of glassware is generally considered more efficient than the enclosing type, and is to be recommended wherever the consideration of efficiency is of primary importance. Enclosing glassware is to be recommended where maximum attractiveness in appearance is more important than efficiency.

Cleaning and Maintenance.—Any efficient lighting system requires careful attention to cleaning and maintenance. Under conditions such as exist in a large department store as well as in any first class lighting installation, the reflectors or enclosing globes must be periodically inspected and cleaned, or the appearance and the illuminating efficiency of the installation will be seriously impaired. Lighting installations require regular—though perhaps less frequent—cleaning, just as do the store windows. It will be shown later how in one instance this detail has been taken care of in a systematic manner and at a very slight cost.

THE McCREERY & COMPANY (PITTSBURGH) STORE

In the summer of 1912 McCreery & Company decided to redesign the lighting equipment of their store, which is located at Wood Street and Sixth Avenue, Pittsburgh, Pa. At that time their lighting equipment consisted, for the main part, of enclosed carbon arc lamps with a considerable number of carbon filament

Fig. 1.—Former lighting equipment of first floor.

Fig. 2.—Night view showing lighting units on first floor.

Fig. 3.—Third floor under old lighting system.

Fig. 4.—Lighting unit used on the second, third, fourth, fifth, sixth, seventh and twelfth floors.

and a few tungsten incandescent lamps. Their purpose in re-designing their lighting equipment was, first, to improve their lighting by providing a higher intensity and more uniform illumination; second, to reduce their lighting expenses, and, third, to provide a modern and attractive installation.

The building is 14 stories high, including the basement and the attic. The ground floor covers a space 100 ft. x 216 ft. (30.48 m. x 75.84 m.) and each of the remaining floors 90 ft. x 216 ft. (27.43 m. x 75.84 m.). The inside area of the first floor is approximately 20,370 square feet (1892.44 sq. m.), and the

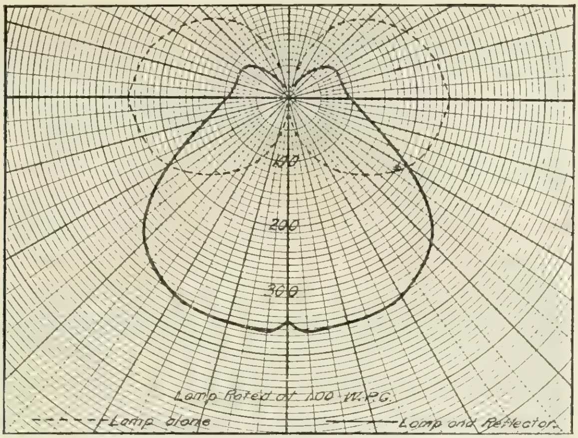

Fig. 5.—Photometric curve of the lighting unit (with a 250-watt clear tungsten lamp) shown in fig. 4.

remaining floors 17,850 square feet (1658.32 sq. m.). The outside of the building is finished in white terra-cotta; the interior, including the fixtures, is of mahogany.

A careful investigation was made of practically all types of lamps and reflecting devices with the view of determining their relative efficiencies and applicability for the various spaces to be lighted. As a result of the investigation, tungsten lamps with various accessories, which are described further on in the paper, were decided upon for the different departments.

All changes were made with practically no changes in wiring;

all the necessary work such as removing the old and hanging new fixtures was taken care of by the electrical department of the store, with no outside assistance whatever. One feature worthy of particular attention and which might well be followed by others in making such changes, is the fact that all the changes on each floor were made in a single night, so that when the sales force arrived the next morning they found a complete new lighting equipment with no trace of the dirt incident to the change. In this way business was not interrupted.

EQUIPMENT OF VARIOUS FLOORS OF THE BUILDING.

Basement (Shoes, trunks and bags).—The lighting equipment consisted of 150 and 250-watt bowl-frosted tungsten lamps and prismatic satin finish reflectors of the extensive type suspended from ceiling by single pendant drops 15 in. (0.38 m.) in length. Ample and satisfactory illumination was obtained in this space and no changes were made.

Basement (Delivery department).—The equipment on this floor consisted of clusters of carbon filament lamps which were replaced by 18 single units consisting of a 60-watt clear tungsten lamp and porcelain enameled shallow dome type steel reflector.

First Floor (Men's furnishings, jewelry, leather goods, stationery, dress trimmings, toilet articles, etc.).—The lighting equipment of this floor consisted of 34 2-light fixtures and 16 1-light fixtures supporting 5-ampere enclosed arc lamps, and 5 4-light decorative brackets on pillars at the rear of the store equipped with all-frosted carbon lamps.

In view of the fact that ornamental and expensive fixtures were already installed, an equipment of lighting accessories in harmony with them was selected. A reflector-ball type of unit of special design was decided upon; it consists of an upper prismatic reflector resting on a stalactite shaped blown globe, the entire unit being satin finished. A noteworthy feature of this globe is the fact that distributions approximating the well-known extensive, intensive, and focusing distributions may be obtained by varying the position of lamp within the globe. A position was

Fig. 6.—Night view of lighting units on third floor.

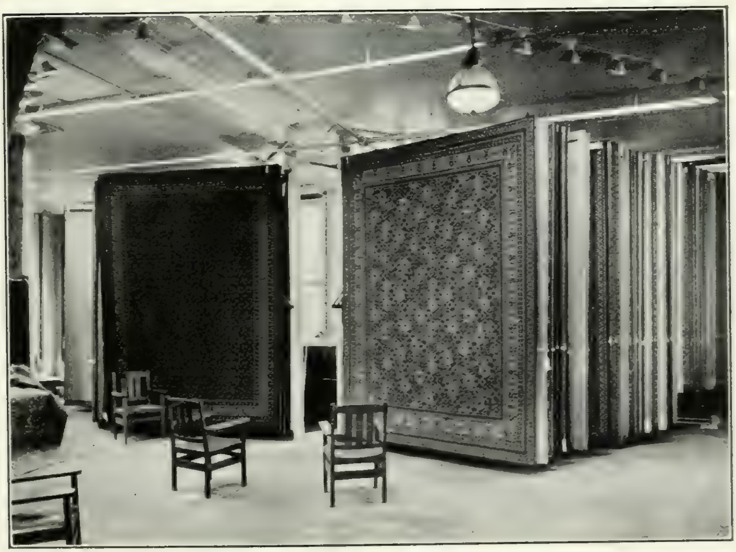

Fig. 7.—Scheme for lighting rug-racks on the fifth floor.

Fig. 8.—Eighth floor with old lighting system.

Fig. 9.—Night view of eighth floor showing new lighting.

determined upon which would give practically an intensive distribution.

Each arc lamp was replaced by a 250-watt clear tungsten lamp. The decorative units on the pillars were replaced by 25-watt bowl-frosted tungsten lamps and decorative shades having a satin finished plate over the bottom, with the exception of the space occupied by lamp bulb.

Second Floor (Bedding and yard goods).—The equipment on this floor formerly consisted of 53 5-ampere direct current enclosed arc lamps with clear inner and opal outer globes. A fairly high intensity of illumination is required on this floor for matching dress goods and similar purposes. Each arc lamp was replaced by a 400-watt clear tungsten lamp placed within a 14 in. (35.56 cm.) 2-piece diffusing glass bowl. This unit[1] (see Fig. 4) consists of a clear stiletto prism reflector mounted over a satin finished shallow bowl, smooth on the outside and having stiletto prisms on the interior surface. These units are mounted in very attractive fixtures having a verde antique finish. The overall length of the fixture is 42 in. (1.07 m.) so that the bottom of unit is approximately 10 ft. 6 in. (3.20 m.) above the floor.

Third Floor (Ladies' suits, waists, and furs).—Fifty-one arc lamps on this floor were each replaced by a 250-watt clear tungsten lamp unit and fixture similar to those used on the second floor (Fig. 4). A number of side bracket units equipped with 60-watt clear carbon lamps were replaced by 25-watt tungsten lamps.

Fourth Floor (Millinery, ladies' and infants' wear).—In the millinery department of this floor 12 arc lamps were each replaced by a semi-indirect unit equipped with a 150-watt clear tungsten lamp. These units are of a design to correspond to the architecture of the room which is of French design of the period of Louis XIV. A soft diffused light is obtained, which is supplemented to a considerable extent by the illumination received from the units used for lighting the millinery show cases. Thirty-three

[1] A "Holophane-Realite" (shown in Fig. 4.).

arc lamps on the main portion of this floor were each replaced by a unit such as used on the third floor (Fig. 4).

Fifth Floor (China, bric-a-brac and rugs).—Fifty arc lamps were formerly used on this floor. Twenty-five were replaced by units like those used on the second floor (see Fig. 4) equipped with 150-watt clear tungsten lamps, and twenty-five by similar units equipped with 250-watt clear tungsten lamps.

A special form of lighting was installed for the rug rack (see Fig. 7). Twenty-five outlets were provided on the circumference

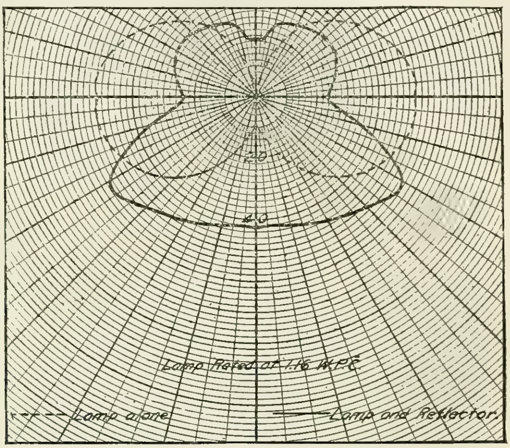

Fig. 10.—Photometric curve of eight-inch light-density opal* reflector with 60-watt bowl-frosted tungsten lamp.

of a semi-circle, the radius of which was approximately 2 ft. (0.61 m.) greater than the maximum swing of the rack arms, the center of the rack being considered the center of the semi-circle. Outlets were located on 2 ft. 6 in. (0.77 m.) centers. Wiring was run in metal moulding and small porcelain receptacles having a metallic bead for use with shade holder were used. Each outlet was equipped with one 40-watt clear tungsten lamp and a 30-deg. angle steel reflector having an aluminumized interior surface. The units were mounted on the ceiling in a pendant position. In order that the light units should not present too strong a contrast

* "Veluria" reflector of the Holoplane Works of the General Electric Co.

with the color of the ceiling, the exterior surfaces of reflectors were also finished with aluminum.

Sixth Floor (Mission furniture, wall paper, draperies, art goods, and ladies' parlor).—Thirty-five arc lamps used for the lighting of the main portion of the floor were each replaced by units similar to those used on the third floor. The ladies' parlor was equipped with four 5-light fixtures using carbon lamps. The fixtures were retained and 15 and 40-watt clear tungsten lamps in 6 in. (15.24 cm.) and 7 in. (17.78 cm.) prismatic balls were substituted for carbon lamps. In the art rooms which are

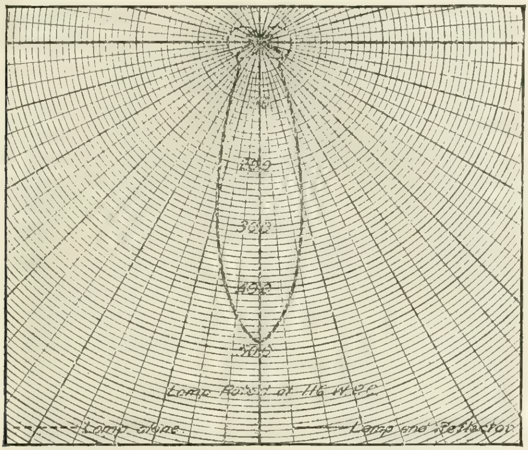

Fig. 11.—Photometric curve of 60-watt clear tungsten lamp and concentrating type reflector used in show windows.

decorated in an oriental manner, five light fixtures which were in use were retained; 25-watt tungsten lamps were substituted for 60-watt carbon lamps and placed within decorative shades similar to those used in the brackets on the first floor.

Seventh Floor (Men's and boys' clothing and general offices).—The general illumination of this floor was taken care of by 45 arc lamps, 36 of which were replaced by 400-watt and 9 by 250-watt clear tungsten lamps in special units like that shown in Fig. 4. As on the second floor, a high intensity of illumination is required, on account of the nature of the goods displayed. A feature which was introduced on these two floors to obtain a

whiter light and allow greater facility in the matching of colors, was the use of lamps rated three volts below the circuit voltage. It is interesting to note in this connection the excellent results obtained, also the fact that even though the lamps are burned above their rated voltage, a life of 800 hours is obtained.

Offices—21 ceiling outlets equipped with 100-watt bowl-frosted tungsten lamps with flat opal shades and 24 2-light desk standards were replaced by 21 ceiling outlets equipped with 150-watt bowl-frosted tungsten lamps and intensive type reflectors.

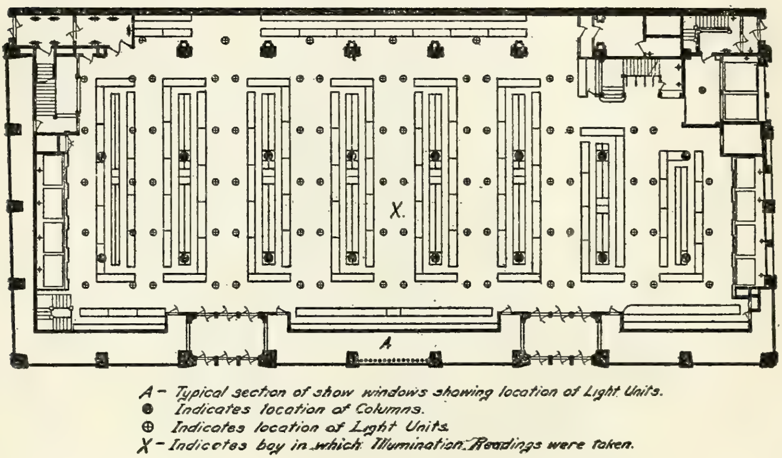

Fig. 12.—Plan of first floor showing location of furniture, pillars, light units, etc.

Eighth Floor (Furniture and victrola department).—This floor was formerly lighted by 85 6-light cluster units consisting of 60-watt all-frosted carbon filament lamps mounted under a large porcelain shade. In the main portion of this floor 80 units were replaced by a single 60-watt bowl-frosted tungsten lamp and an 8 in. (20.32 cm.) opal reflector fastened in the present fixtures.

The victrola department is now illuminated by five 150-watt clear tungsten lamps in semi-indirect lighting units.

Ninth Floor (Dining room and kitchen).—In the dining room 71 6-lamp cluster fixtures had been installed; each lamp was a 30-watt clear carbon filament lamp. The fixtures were retained;

15-watt all-frosted tungsten lamps were used to replace 30-watt carbon lamps. Numerous minor changes were also made on this floor; 60-watt carbon lamps were replaced by 25-watt tungsten lamps.

In the kitchen 11 arc lamps were replaced by 250-watt clear tungsten lamps.

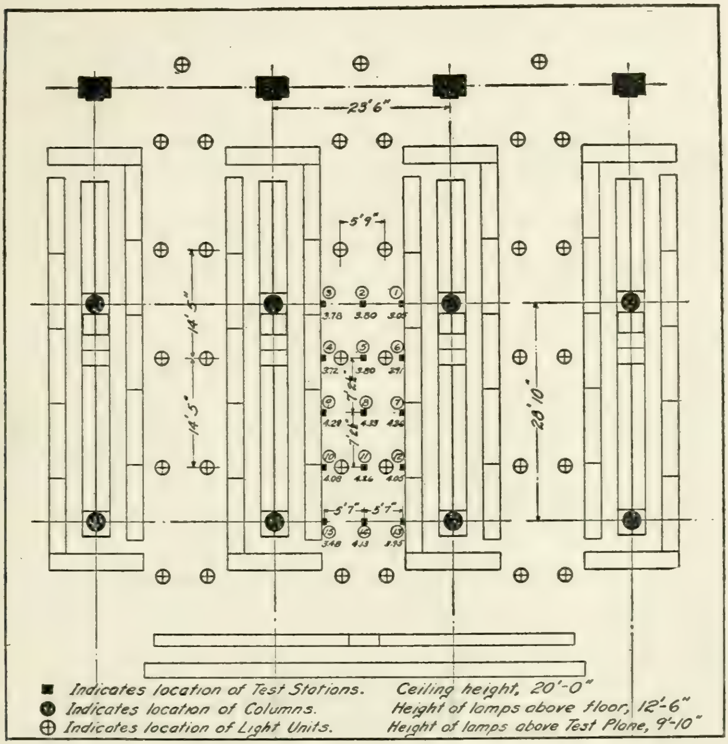

Fig. 13.—Section plan of first floor showing location of illumination test stations.

Tenth Floor (Furniture, employees' recreation and lunch room).—Thirty-two arc lamps were replaced by 150-watt clear tungsten lamps equipped with extensive type prismatic reflectors. Seventy-six 60-watt clear carbon lamps were each replaced by a 25-watt tungsten lamp.

Eleventh Floor (Buyers' offices, receiving and stock rooms).—The equipment formerly consisted of 19 arc lamps and 13 4-light

clusters of 60-watt clear carbon filament lamps. Thirteen of the arc lamps were replaced by 250-watt and 6 by 150-watt tungsten lamps. Each 4-light cluster was replaced by a single 60-watt tungsten lamp and extensive type prismatic reflector.

Twelfth Floor (Fitting rooms and wash-rooms).—Forty arc lamps were formerly used. Ten were replaced by 250-watt tungsten lamps in the special unit shown in Fig. 4 and 30 by 150-watt tungsten lamps and opal shades.

Thirteenth Floor (Attic).—Six arc lamps and 100 60-watt carbon drop lights were formerly used; 4 of the arc lamps were replaced by 150-watt tungsten lamps, and 2 by 100-watt tungsten

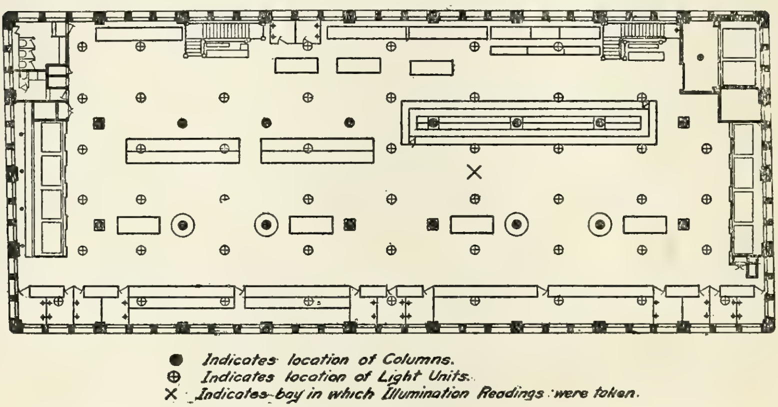

Fig. 14.—Plan typical of the general arrangement of furniture, light units, etc., on the upper floors, with exception of eighth.

lamps. Each 60-watt carbon lamp was replaced by a 25-watt tungsten lamp.

Show Window Illumination.—An average section of these windows is 23 ft. 6 in. (7.16 m.) long and 8 ft. (5.49 m.) deep, the ceiling is 19 ft. (5.79 m.) above the bottom of the show case. The plate glass extends to a height of 12 ft. (3.66 m.). Prism glass being used at the top. The sides and back of the windows up to a height of six feet are covered by a dark green velvet curtain or drapery; clear glass plates are used above this to let as much daylight into the store as possible.

The former equipment for windows consisted of a total of 326 60-watt clear carbon lamps mounted in a mirrored trough placed back of the transom bar. The present equipment consists

of a total of 195 60-watt clear tungsten lamps; 15 are used in each section, the outlets being located back of transom bar on approximately 14 in. (0.35 m.) centers. Each lamp is equipped with a 100-watt size concentrating type prismatic reflector; the units are mounted at an angle so that tip of the lamp is pointing at a line on

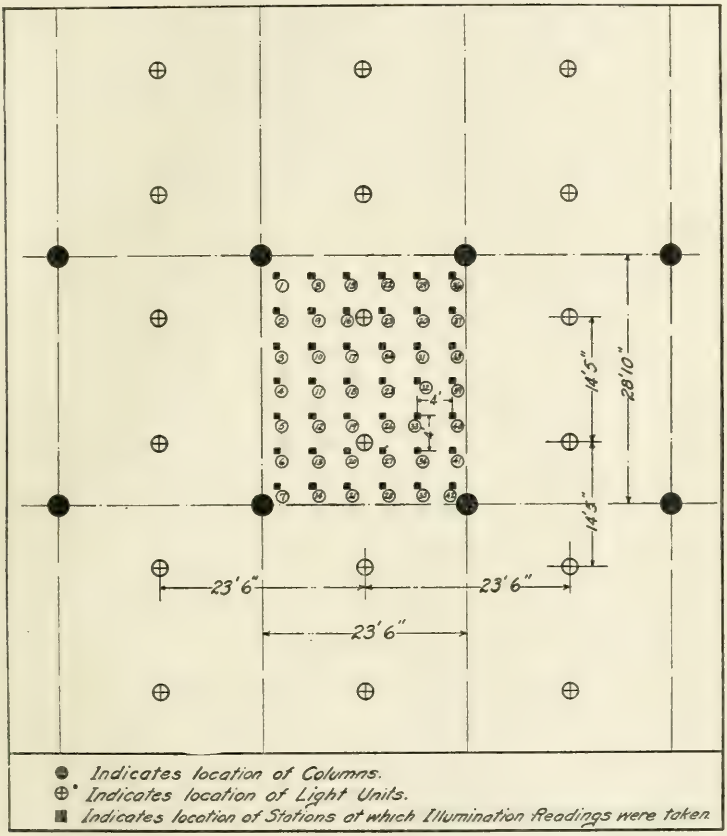

Fig. 15.—Section plan of third floor showing location of illumination test stations.

floor approximately two-thirds of the distance from plate glass to opposite enclosing wall of window. This angle is found to be the best for the average form of window dress, but in exceptional cases, provision is made for varying the angle. The light units are concealed from the view of persons standing on sidewalk by means of an ornamental drapery placed between the light units and plate glass. The units are wired so that alternate

lamps are on the same circuit, allowing one half of the units to be used on ordinary occasions and all units when desired. By using a larger size reflector 100-watt lamps may be used on special occasions when a higher intensity of illumination is required in any one section for display of special goods. With a wattage allowance of but 4.7 per square foot (0.09 sq. m.), very satisfactory illumination has been obtained. It will be noted from fig. 10 that a very small amount of light is received on the sidewalk; practically all the light is directed on the goods displayed.

In order to keep the light from the upper part of window and also from interior of the store, a metal strip has been placed above the light units and painted white on the under side. A small valance has been suspended from this strip which serves to cut off the light from the interior of the store. The fact that some light is received directly on the sidewalk as well as additional light caused by direct reflection from the goods on display, is worthy of attention, since such light serves to attract the attention of the passersby.

Show Case Illumination.—The illumination of show cases in a large department store is of very great importance and a large factor in the use of energy. In the present instance the show cases were formerly lighted by carbon filament tubular type lamps, but are now lighted far more satisfactorily by the new tungsten 25-watt drawn wire tubular type lamp which is particularly suited for this class of lighting.

NOTES ON THE ILLUMINATION TESTS.

After the installation was made, illumination tests were conducted in various departments to determine the intensity and uniformity of illumination obtained.

Test No. 1 (First floor; buff ceilings—soiled condition; 6 years since painted—buff walls; dark wood floor; mahogany fixtures).—The arrangement of the furniture made it necessary to select test stations as shown in Fig. 13. Horizontal illumination readings were taken on a plane 32 inches (0.81 m.) above the floor, which is the height of the counters throughout store. The values obtained at various stations are shown in Fig. 13. All values were corrected for any changes from rated voltage of lamps which were noted.

Test No. 2 (Third floor; buff ceilings—soiled; walls buff; dark green carpet; mahogany fixtures).—Test stations were selected as indicated in Fig. 15, because of few obstructions in this bay. Horizontal illumination readings were taken on a plane 32 in. (0.81 m.) above the floor or at the counter level. The following table indicates readings obtained at various stations:

Station	Foot-candles	Station	Foot-candles	Station	Foot-candles
1	1.93*	15	3.94	29	2.60
2	2.09	16	4.42	30	2.93
3	2.12	17	3.95	31	2.76
4	2.11	18	3.62	32	2.61
5	2.28	19	4.08	33	2.76
6	2.30	20	4.40	34	3.08
7	1.93*	21	3.94	35	2.60
8	2.84	22	3.63	36	1.89*
9	3.11	23	4.48	37	1.99
10	2.95	24	4.03	38	2.01
11	2.77	25	3.62	39	2.09
12	2.93	26	4.13	40	2.13
13	3.01	27	4.12	41	2.28
14	2.84	28	3.63	42	1.89*

* Indicates light partially obstructed by column.

Test No. 3.—The tests were conducted on another floor on which the change from arc to tungsten lamps had not yet been made. Tests were made in a bay occupying the same relative position as bay in test No. 2, and readings were made at the same stations under practically similar conditions. The readings obtained were as follows:

Station	Foot-candles	Station	Foot-candles	Station	Foot-candles
1	1.56*	15	2.33	29	1.98
2	1.62	16	2.80	30	2.07
3	1.55	17	2.93	31	1.95
4	1.51	18	2.72	32	1.77
5	1.45	19	2.67	33	2.32
6	1.49	20	2.38	34	2.17
7	1.33*	21	2.28	35	1.58
8	1.92	22	2.36	36	1.56*
9	2.04	23	3.18	37	1.56
10	2.00	24	2.84	38	1.48
11	1.92	25	2.09	39	1.59
12	2.24	26	2.79	40	1.65
13	2.02	27	3.23	41	1.58
14	1.95	28	2.52	42	1.39*

* Indicates light partially obstructed by column.

Height of lamps above floor 10 ft. 6 in. (3.20 m.).

Height of lamps above test plane, 7 ft. 10 in. (2.39 m.).

4

Test No. 4 (Eighth floor; buff ceilings—soiled; dark green walls; dark floor; mahogany fixtures).—Horizontal illumination readings were taken on this floor at a plane 32 in. (0.81 m.) above the floor at similar stations and under similar conditions as Test No. 2, with the exception that four light units are provided per bay, each consisting of a 60-watt bowl-frosted tungsten lamps in 8 in. light opal reflectors.[1] The results of test were as follows:

Station	Foot-candles	Station	Foot-candles	Station	Foot-candles
1	0.16*	15	1.21	29	1.20
2	1.21	16	1.21	30	1.32
3	1.15	17	1.13	31	1.28
4	1.17	18	1.00	32	1.19
5	1.15	19	1.11	33	1.21
6	1.16	20	1.16	34	1.18
7	0.82*	21	1.12	35	1.13
8	1.15	22	1.19	36	0.86
9	1.18	23	1.19	37	1.38
10	1.16	24	1.19	38	1.31
11	1.12	25	1.11	39	1.26
12	1.16	26	1.13	40	1.27
13	1.17	27	1.16	41	1.20
14	1.09	28	1.15	42	1.03*

* Indicates light partly obstructed by columns.

Height of lamps above floor approximately 10 ft. 6 in. (3.20 m.).
Height of lamps above test plane approximately 7 ft. 10 in. (2.39 m.).

In all the foregoing tests it was necessary to choose bays for test purposes which were practically free from obstruction, and while the readings obtained for any one bay if properly considered will give a fair idea of the average intensity for that bay, these figures have not been given inasmuch as they might be construed as representing average intensity for whole floor space.

CLEANING AND MAINTENANCE OF PRESENT INSTALLATION.

A careful system for regular inspection and cleaning has been initiated in this store whereby all units in the building are brushed off with a stiff brush and cloth once every two weeks, and each unit is taken down and washed thoroughly once each month. The cost of cleaning, including labor and materials, is approximately $350 per year for approximately 1,000 units

[1] Holophane "Veluria."

installed. Since the units are thoroughly cleaned once per month, the cost of cleaning per unit will be approximately 3 cents, which includes one dusting and one washing. A fair division of this cost would be ½ cent per unit for dusting and 2½ cents for thorough cleaning. Under such a system the illuminating efficiency is kept at a practical maximum. It is probable, however, that in other places where dirt and dust conditions are not as severe, that the cleaning could be done at less frequent intervals. The above-given figures represent a very small part of the operating expense, and are considerably less than cost of trimming and other maintenance charges incident to the operation of the old system.

CONCLUSION.

With the aforementioned changes, this store now has a thoroughly modern and attractive lighting equipment, a considerably higher intensity of illumination at a saving in operating expense of over 50 per cent. The figures given for cleaning and maintenance serve to indicate what may be accomplished by systematic attention to this detail at a cost probably not as great as the cost of cleaning the windows.

The writer desires to take this opportunity of heartily thanking Messrs. L. J. Kiefer, of the McCreery Company, and P. C. Keller for the valuable assistance which they rendered him in collecting the data for this paper.

DISCUSSION.

Mr. G. H. Stickney: This paper contributes some important data on the recent practise in department store or rather, as I should class McCreery's Store, dry goods store lighting. It is, therefore, of great value to all those who have lighting problems of this character.

A large dry goods or department store combines in one institution a large number of departments or stores. As such, each department has its own lighting requirements pertaining to the class of merchandise handled. Thus, we find the problems of the silk store, furniture store, picture store, jewelry store, restaurant, etc., but in addition, since these are all brought together in one establishment, the lighting of each must bear a

relation to all the others in order that we may have a unity and dignity in keeping with the large institution.

Referring to some detail points in the paper, I note that the author believes that the brightness of the lighting units should be equal to that of the ceiling. From my own observation, I am led to the opinion that, for appearance sake, it is desirable in an installation of this type to have the units preferably brighter than the ceiling, although this should not, of course, be carried far enough to introduce objectionable glare.

As to color values, there has, in the past, been considerable difference of opinion regarding the requirements of dry goods stores and the practise in different cities has differed. There are certain departments, such as dress goods and silk departments, where accurate color selection is desirable; both daylight and the prevailing evening light should be available so that goods for street wear may be selected by daylight and those for evening wear by artificial light. One condition which is often overlooked is that a high intensity, say 20 foot-candles or more, is necessary for accurate daylight selection of delicately colored materials. Moreover, the only accurate color matching artificial lights are all relatively inefficient and, as a result, it is not practicable, in the present state of the art, to light an entire department by artificial light for daylight color matching. The best solution of this problem is that adopted by the McCreery Company, namely, that of providing small rooms or booths where artificial daylight of the proper diffusion and intensity can be obtained in the evening, and correspondingly, evening light in the daytime. Even where color matching booths are not provided, nearly all the large dry goods and department stores are turning to the tungsten filament lamp. Among these may be mentioned Marshall Field Co., Carson Piru Scott & Co., Mandel Brothers, Rothchilds and The Fair in Chicago, and the McCreery Co., Gimbels and Greenhut-Siegel-Cooper Co., in New York. There are many others nearly, if not equally prominent.

As expressed to me by the manager of one of the large dry goods stores in Chicago, the pleasing appearance of his store under the tungsten filament light much more than compensated for the color matching advantages of any other light. There are

relatively few departments in such a store where accurate color matching is necessary, while in other departments, the warm color tone is considered so important that it is often the practise to exclude daylight by mean of shades or screens and display the goods throughout the day by the warm light from the tungsten filament lamp.

The enterprise of this company in making the new installation without in any way interfering with the sales activity of the store is commendable. I know that this meant considerable planning beforehand. In many stores even the simple maintenance is not planned so as to avoid such interference.

Another point worthy of mention is the excellent clean condition in which we found the installation in our inspection to-night. We cannot emphasize too much the importance of cleanliness in maintaining the efficiency and appearance of any lighting system. The practise of regular inspection and cleaning at prescribed intervals is the only way to insure this result, and, as brought out in the paper, the cost, even in Pittsburgh, is surprisingly low.

The whole installation is admirably adapted for its purpose and is one of the best I have seen anywhere.

Mr. W. M. Skiff: With reference to showcase lighting, I would like to call attention to the reduction in heat in showcases due to the use of tungsten filament lamps. With a 50 watt tubular gem filament lamp the glass on showcases is often heated and the breakage of the glass, due to expansion, is common. With the tungsten filament lamp of half the wattage 28 per cent. more candle-power is obtained than with the carbon lamp, and there is less liability of breakage of the glass showcase due to heat.

In connection with the color of light, my attention was recently called to a theatrical company which made a practise of carrying an equipment of strip and border lights composed of 32 candle-power carbon filament incandescent lamps, part of which were amber dipped. This was departing to a considerable extent from daylight values and the reason given was that the make-ups were artificial and, therefore, required other than daylight values to produce the best results. It is no doubt true that daylight value

in stores is not necessary for the proper illumination of materials which will be used in the home or elsewhere under incandescent electric lamps.

MR. S. G. HIBBEN: With reference to the question of maintenance, it would seem that in retail sales houses where the cleaning is not as thorough or does not follow as definite a schedule as in this store, that of reflectors of equal efficiency the one which will show dirt, and consequently the need of proper cleaning and up-keep, is preferable.

On going through the store I also noticed considerable glare from the upper parts of the prismatic units, and it is suggested that frosting of these upper portions would be highly advisable. A commendable point I wish to call attention to is the fact that the new units on most of the floors are placed higher than were the replaced arc lamps. In the low position, the arc lamps were decidedly unpleasant.

On the page referring to window lighting it is stated that a large reflector is used so that small or large lamps may be employed as desired. I would like to ask if it is not true that in this case, where the small lamp is used in the reflector designed for the next larger sized lamp, that the candle-power distribution is not changed, since the filament position is different than that for which the reflector was originally designed.

I note also that on different floors the same sized glass accessories are used, but different sized lamps are employed. I believe the author has neglected to mention, in this connection, the very desirable feature of these fixtures is that there is provision made for a mechanical adjustment to allow of nearly the same distribution when using various sizes of lamps.

It must be remembered that the paper cannot be used as a basis of design, since it is essentially a description of an installation. Some of the main units employed are admittedly not the most efficient that might have been obtained. They were not selected on account of color values; their maintenance cost is not low; nor is their deterioration small. It is said that their harmonizing and decorative appearance determined their selection, and of course when one discusses taste there is a wide latitude of opinion.

Mr. Ward Harrison: With reference to maintenance, we have found that with open reflector equipment approximately one-half of the deterioration in the illuminating value of the reflectors arises from the deposit of dust on the outside of the reflectors, and one-half is due to dust on the inside and on the lamp bulb. When the lamp is enclosed as in the McCreery fixtures, one-half of this deterioration is largely eliminated. This, with the fact that a clear instead of a bowl-frosted lamp is used, makes up in a large measure for the lower efficiency to be expected because of enclosing the lamp.

The complete change of the lighting equipment on a floor in one night is a commendable plan because of the fact that the contrast in the colors of the arc and incandescent lamps is not pleasant and often store employees are not in favor of the change when they see the two systems thus compared. Both illuminants vary from daylight; one has an excess of red, the other of blue rays; and in juxtaposition the effect is not pleasing.

In passing through the store I noticed that the ceilings were of such a color that their coefficient of reflection was not high. Had they been painted white, the efficiency of the installation would have been increased appreciably and the contrast in brightness between light sources and the ceiling would also have become less marked.

With reference to the illumination tests, I would like to ask Mr. Shalling whether the foot-candle values given are in each case representative of the whole floor area, and also at what period during the life of the lamps the tests were conducted; in a word, whether the data as given are representative of average conditions including depreciation due to dust.

Mr. L. J. Kiefer: The old equipment consisted of standard enclosed carbon arc lamps, not intensified arc lamps.

The heat formerly given off by carbon lamps in showcases where jewelry was displayed was such that injury frequently resulted to jewel settings, so much so that it was a common thing to send material back to the factory to have the stones reset. The use of high efficiency tungsten lamps has eliminated this trouble.

The question of color values has been carefully considered in connection with the lighting of the McCreery & Company store.

On the second floor there is provided convenient space next to the windows where clerks may show silks and dress goods under daylight. For dark days and during a few hours in the evening in some seasons, there is also a special room equipped so that a customer may see goods under both evening and daylight conditions. An intensified arc with a color screen illuminates the room, forming a circular panel of white light on the ceiling. Incandescent lighting is also provided and can be conveniently switched on as a customer desires.

Mr. H. W. Shalling (in reply): The units formerly used in this store were not the intensified type of arc lamps, but were standard enclosed carbon arc lamps.

In designing the installation, it was found by careful experiments that satisfactory color matching for most practical purposes could be obtained by the use of the tungsten filament lamp. In some cases a much closer approximation to true daylight values was obtained by burning the lamps above their rated voltage. For particular cases, daylight can be used as a general rule by carrying goods to the windows; a booth is also available with a specially prepared color matching device.

In answer to Mr. Harrison's questions, I would say that the areas chosen for test purposes were representative; all lamps on any one floor were burning during the tests. Slightly different intensities might be obtained near the windows or side walls, but an average of the values found can be considered to be practically an average for the entire floor space. The units had been in use about three months when tests were made.

In the cut glass department, clear reflectors and clear lamps are used. In the showcases a metal reflector having a polished surface is used. In the millinery showcases, polished metal reflectors are also used.

In answer to Mr. Hibben's remarks, it will be noted that in the clothing department where 400 watt units are employed with lamps burned above their rated voltage, that excellent color values are obtained while the glare is not at all objectionable or even noticeable to the average customer, considering the time such customer would usually spend in this department.

On the first floor in order to obtain the required intensity and

to get the desired ornamental effects, it was necessary to use about twice the wattage ordinarily used on the other floors.

In designing an installation for a store of this character it is necessary to carefully analyze conditions on the various floors in order that there will not be too great a sameness to the units employed. The units should be in harmony with the architectural and fixture conditions.

TESTS FOR THE EFFICIENCY OF THE EYE UNDER DIFFERENT SYSTEMS OF ILLUMINATION AND A PRELIMINARY STUDY OF THE CAUSES OF DISCOMFORT.*

BY C. E. FERREE.

Synopsis:—Besides outlining (I) the problem which confronts the investigator who would determine the effects of various lighting systems on the eye, this paper discusses: (II) the scale or general level of efficiency of the eye under different systems of lighting, with brief comments on the conventional tests for the efficiency of the eye such as, (*a*) color discrimination, (*b*) brightness discrimination, (*c*) visual acuity—the latter tests, modified, it is contended are adequate for the determination of the general level of efficiency of the unfatigued eye; (III) loss of visual efficiency as the result of a period of work—here it is contended that each of the aforementioned tests fails to show a true loss of visual efficiency, and a new test is described. The paper is concluded (IV) with a brief statement of some of the causes of ocular discomfort under various conditions, and a description of a method of making a comparative estimate of discomfort.

I. INTRODUCTION.

In 1911 the American Medical Association appointed a committee to study the effect of different lighting systems on the eye. The writer was asked to share in the work of this committee. The problem presented to him was to furnish tests that would show the effect of different lighting systems on the eye and more especially to devise, if possible, a test that would show a loss of efficiency as the result of three or four hours of work under an unfavorable lighting system. It is the purpose of the following paper to give a preliminary report of the work that has been carried on by the writer in this field during the past year.

Confronting the problem of the effect of lighting systems on the eye, it is obvious that the first step toward systematic work is to obtain some means of making a definite estimate of this effect. The prominent effects of bad systems of lighting are loss of efficiency, temporary and progressive, and eye discomfort. Having devised methods which after six months of testing he has found to be accurate and practicable, the writer has under-

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taken to determine (1) the lighting conditions that give in general the highest level or scale of visual efficiency, (2) the conditions that give the least loss of efficiency for continued work, and (3) the conditions that cause the least discomfort. This plan of work, it is scarcely needful to remark, will involve a wide range of experimentation. The crux of the problem, as the writer conceives it, is, however, to secure reliable methods of estimating effect. Having these methods, the factors whatever they may be, intensity, quality, position of light relative to the eye, etc., can be varied one at a time and the effects be determined. From these effects it should not be difficult to ascertain what lighting conditions are best for the eye and what is the relative importance of the factors that go to make up these conditions. Further it should be possible on the practical side to test out and perfect a lighting system, so far as its effect on the eye is concerned, before we put it on the market.*

In this report nothing more will be attempted than to indicate what methods may be used in the three steps of the problem as outlined above.

II. THE SCALE OR GENERAL LEVEL OF EFFICIENCY OF THE EYE UNDER DIFFERENT SYSTEMS OF LIGHTING.

A general survey of the field shows that at different times the following tests have been used in one capacity or another for determining the efficiency of the eye: brightness discrimination, color discrimination, and visual acuity. No extensive use, if any at all, has been made of any of these with the exception of visual acuity in connection with problems of the type here considered, but the fitness of their application in some form to such problems is evident at a glance. If the eye's efficiency is to change at different times and under different conditions of lighting, it should be manifested in changes in brightness discrimination, color discrimination, or visual acuity. The first step in our work would, then, seem to be to devise for these points tests which are sufficiently sensitive for use in work of the kind we have in hand. The general nature of these tests is too familiar to need detailed mention here. A few special points may, however, be given in passing. (1) The threshold or limen test is the most sensitive and practical

* This latter point was suggested to the writer by reading Dr. Ives' discussion of this paper (p. 57).

for color sensitivity. In making this test the pre-exposure[1] and the surrounding field[2] should be of a gray of the brightness of the color at or near its threshold value. Further, the illumination of the room must be kept constant from test to test.[3] If the colored light is to be obtained by reflection, disks of standard

[1] By pre-exposure is meant what the eye rests on immediately preceding its stimulation by color. It is obvious that there must always be some pre-exposure and, unless care be taken to eliminate its effect, it will influence the eye's sensitivity to color. Even closing the eye, as is often done before stimulating by color, is the equivalent of giving a black pre-exposure. All color must of course be eliminated from the pre-exposure. It should also be of the same brightness as the color by which the eye is to be stimulated. If not it gives a brightness after-image which mixes with the succeeding color impression and reduces its saturation. This reduction of saturation takes place apparently at some physiological level posterior to the seat of the positive, negative, and contrast color processes commonly supposed to be located in the retina. (See Ferree and Rand: "The Fusion of Brightness with Color—The Locus of the Action," *Journal of Philosophy, Psychology and Scientific Methods*, VIII, 1911, p. 294.) If the pre-exposure is lighter than the color it adds by after-image a certain amount of black to the succeeding color impression and, if darker, it adds a certain amount of white. Since white inhibits color more than black, the effect of a dark pre-exposure is to reduce the sensitivity to color more than the effect of a light pre-exposure. But since both white and black as after-effect reduce the sensitivity to color, the eye is rendered more sensitive when no after-image is given, *i. e.* when the pre-exposure is of the same brightness as the color. The pre-exposure therefore should be to a gray of the brightness of the color. No brightness after-image will be added thereby to the succeeding color impression to modify either its saturation or color tone.

[2] When the surrounding field is either lighter or darker than the color, brightness is induced by contrast across the colored surface. When the surrounding field is lighter than the color, a certain amount of black is induced, and when darker, a certain amount of white is induced. As stated above, the mixture of this white or black with color, although it does not alter the amount of colored light coming to the eye. reduces the saturation of the color. The effect of brightness contrast can be eliminated only by making the brightness of the surrounding field a gray of the brightness of the color. This can be done by means of a gray screen around the color, or by a larger gray disk in case a color mixer is used.

[3] In case the colored light used for the stimulus is obtained by reflection from a pigment surface, a change in the general illumination of the field of vision affects the results of the sensitivity tests in the following ways. (1) It changes the amount of colored light coming to the eye. (2) By changing its brightness adaptation it changes the sensitivity of that part of the retina upon which the colored light falls. (3) By changing the sensitivity of the eye to brightness after-image and contrast, it changes the amount of brightness added to the color as the result of pre-exposure and surrounding field, and therefore changes the effect of pre-exposure and surrounding field upon the color impression. Moreover, the effect of pre-exposure and surrounding field cannot be eliminated even when both are made of the brightness of the color for some given illumination, unless that illumination be kept constant throughout the test for, when it changes, the brightness of the color and of the grays used as pre-exposure and surrounding field does not change in equal amounts; hence, the brightness equality which is needed cannot be maintained. In case the colored light is not gotten by reflection from a pigment surface but is obtained from monochromatic sources from standard filters or from the spectrum, only the last two of the factors stated above influence the results of the tests for color sensitivity. In the tests made by the writer, the general illumination was rendered constant by methods to be described later in the paper.

Although for the purposes of this work the tests for color sensitivity could never be conducted in the dark-room, still it may be of general interest to note at this point that the elimination of the effect of pre-exposure and surrounding field cannot be accomplished in work on color sensitivity done in the dark-room, because in the dark-room the pre-exposure and surrounding field cannot be made of the brightness of the color. They will always therefore exert an effect on the color impression. Moreover since the colors all differ in brightness, this effect will be exerted in different amounts on the different colors. That is, the amount of brightness added by after-image or contrast depends upon the amount of brightness difference, respectively, between pre-exposure and color and surrounding field and color. As stated above this amount, when working in the dark-room, will be different for the different colors. For this reason and also because even the same amount of brightness excitation acts with different degrees of strength upon the excitation set up by the different colors, it is especially important that no work on the comparative sensitivity of the retina to the different colors should be done in the dark-room. It should be done in a light room of a constant intensity of illumination and with pre-exposure and surrounding field in each case of the brightness of the color to be used. In this way alone can all the factors which influence the sensitivity of the retina, extraneous to the source of light, be eliminated.

colored and gray papers (*e. g.,* the papers of the Hering series) may be used on a color mixer.[4] If, on the other hand, it is desirable to use the light of the spectrum or the light transmitted through standard filters, the colored light may be cut down to the threshold value by means of a sectored disk, the sectors of which should be covered with a gray of the brightness of the color at or near its threshold value. (2) For brightness discrimination also the threshold or limen test is the most sensitive and practical, but when made in a well-illuminated room, it becomes in effect a test for a just noticeable difference. This test may be performed at different points in the brightness scale, *e. g.,* when the standard is black, near mid-gray, or white. As before, disks of standard papers may be used on the color-mixer, or the light from a given source may be varied by means of a sectored disk.[5] (3) Visual acuity tests of the Snellen type, especially when used in work in which it is required to make successive tests on the same person, are open to the following objections. (a) The judgment is in terms of recognition. A letter may be recognized when it is not seen clearly. In any judgment based on the recognition of even a single letter, memory plays an important role. It is, so far as the writer knows, impossible to standardize this memory factor and to obtain results strictly in terms of acuteness of vision. (b) The test card is made up of quite a long series of letters. As the test progresses the letters are memorized more and more completely. It is practically impossible to eliminate this progressive error when a number of successive judgments have to be

[4] In making the tests with reflected light, two sets of disks are mounted on a color mixer (*a*) an outer disk of gray of the brightness of the color to be used, and (*b*) an inner disk made up of this gray and the disk of color. To the inner gray disk, varying proportions of the color are added until the threshold value or just noticeable color is obtained. To facilitate the judgment of just noticeable color, the inner disk of gray plus color is compared with the outer disk of gray as a standard. Since both grays are of the brightness of the color, the addition of the colored sector to the inner disk produces no change of brightness either to confuse the judgment of noticeable color, or to affect the intensity of the color excitation actually aroused. In getting the threshold value, the method of ascending and descending series should be used, that is, beginning with equality, the variation is towards noticeable difference and beginning with a difference greater than noticeable, the variation is towards equality. An average of the two sets of results is taken for the threshold value.

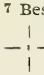
[5] When the test is made with reflected light two sets of disks, an outer and an inner, are mounted on the color mixer. Each set is made up of one white and one black disk. Both sets of disks are set at the point in the brightness scale from which the variation towards white or black is to be made. One is kept constant and the other is changed until the judgment different is given. In making the judgment the method of ascending and decending series is used and the results are averaged for the difference limen. This difference limen is taken as the measure of the observer's sensitivity to brightness or white light.

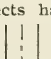
made as is the case before a final result is reached in any single visual acuity test and as is especially the case when a number of successive tests have to be given to the same person, which happens in much of the work involved in the solution of the problem here proposed. It might be supposed that the memorization of the series could be broken up by using in each successive judgment in a single test or in the successive tests, as the case may be, cards having a different distribution of the letters in the series. Considerable inconvenience would, however, be involved in giving the tests in this way and besides no guarantee could be had that each judgment would present the same degree of difficulty. That is, the series is made up of similar and dissimilar letters. The dissimilar letters can be distinguished from each other with less difficulty than the similar. It is practically impossible to distribute the letters so that the individual tests may be equally rigorous. This objection can, of course, be eliminated in part by a careful selection of the test letters, but not entirely because a series of letters uniformly similar cannot be found. (c) The Snellen series contains quite a large number of letters. The eye is found to fatigue and vision to blur before the series is completed. This introduces an error which it is practically impossible to render constant.

All of the above objections were eliminated in the tests finally adopted by us by changing the type of judgment and by making the test object in one case two parallel vertical lines stamped 1 mm. apart on a white card[6] and in another the letters li printed in small type.[7] In using these cards the observer's acuity of

[6] The card is mounted on a sliding carrier which runs on a track made of two meter rods fastened end to end on a folding base. The base is mounted on adjustable stands fastened to a table. When making the test the apparatus is so adjusted that the track carrying the test card is just below and close to the observer's eye. In order that the observer's head may be held steady he is required to bite an impression of his teeth, previously made and hardened in wax on a mouth-board, which is rigidly fastened by a heavy iron rod and accessories to the table supporting the track and carrier.

[7] Besides the letters li the writer would recommend the following figures as test objects.

(1) . The test is to distinguish clearly the dot at the center. A test object in the shape of a cross has the advantage of affording a steady control of fixation. According to photographic records of involuntary eye-movement, where a variety of fixation objects has been used, the cross is found to give the best control of fixation.

(2)  or . In these figures also the test is to distinguish the dot clearly. The former figure, however, is a little too complicated. There is both a tendency to lose the dot and for the lines to run together on either side. A simpler criterion gives an easier and safer judgment. Doubtless with a little effort other figures can be found possessing still greater merit as test objects.

vision is determined by the distance at which he can just clearly distinguish in every detail the two test objects. The results are thus rendered directly in terms of clearness of vision, and there are no progressive errors introduced by memory and fatigue.

We have good reason to believe that the brightness sensitivity, color sensitivity, and visual acuity tests rendered sensitive and adapted to our purpose in the manner described above will serve as a measure of the general level of efficiency of the unfatigued eye under different systems of illumination. For example, they show considerable difference in result when the tests are given under three types of lighting now in use: namely, systems of direct lighting, systems of indirect lighting, and daylight. In each of these cases, the intensity of the light falling on the test object measured in foot-candles is kept the same. The tests can not, however, be depended upon to show a loss of efficiency of the eye as a result of three or four hours of work even under a very unfavorable lighting system.

III. LOSS OF EFFICIENCY AS THE RESULT OF A PERIOD OF WORK.

We have no reason to believe that the brightness and color sensitivity tests have failed to show that the eye loses in efficiency as the result of a period of work under an unfavorable lighting system because of any fault in the tests. The tests used are the product of several years of study by the writer of the sensitivity of the eye to brightness and color and of the factors that influence this sensitivity. There is doubtless very little, if any, loss of sensitivity during this length of time. In fact it is commonly believed that the brightness and color processes are compensating in nature. The case is quite different, however, with the conventional visual acuity test, or even with the modification of it described above. Although brightness and color sensitivity are factors influencing the visual acuity test, still in every case to which it may be applied, it is predominantly a test of the refracting mechanism of the eye and its muscular control. In fact our results for the tests of brightness and color sensitivity teach us that when applied to the case in hand in which there has been no change in the quality and intensity of the illumination or of the refracting mechanism from the beginning to the close of work,

the results of the visual acuity test may be ascribed practically entirely to changes in the muscular control of the refracting mechanism, or at least to changes in the muscular control of the eyes as a whole.[8] Now the visual acuity test, when it is confined to a momentary judgment of clearness of vision, is not adapted to show a loss in muscular efficiency because, although this efficiency may have been lowered enormously, it may rise momentarily under the spur of the test to its usual level, or at least to the level obtaining at the beginning of work. Just as the runner may, under the spur of his will, equal in the last lap of his course the highest speed he has attained at any other point in the course; so may the flagging muscles of the eye be whipped up to their normal power long enough to make the judgment required by the visual acuity test. It was the feeling of all our observers that at the close of work under the system of direct lighting installed in our laboratory the eye had lost heavily in efficiency. A great deal of discomfort was felt. The test was painful and was accomplished only with decided strain. Still the judgment could be made apparently with as much accuracy as at the beginning of work. But just as the runner finishing his course cannot long keep up his extra burst of speed, so might we expect that the eye cannot sustain its extra effort. This analogy led the writer to continue the visual acuity test through an interval of time. After considerable experimentation an interval of three minutes was chosen as best suited for our purpose. Our surmise proved to be correct. The fatigued eye cannot keep up its extra effort. The results of the test showed an enormous loss of efficiency as

[8] Before the writer would speak with full certainty, however, that the retina loses none of its power to function for color and brightness sensation during the above stated period of work, he would feel it necessary to perform another kind of test for color and brightness sensitivity. This test has been devised by him especially to meet the needs of this problem. In this test the element of time is introduced. It is possible that the retina may have lost in power to give color and brightness sensation as the result of a period of work even when the conventional test based on a momentary judgment, shows no loss of sensitivity. That is, it may be more susceptible to fatigue as the result of the preceding work. To determine this, a fatigue test should be run at the beginning and close of work. For color this may be done in two ways. (1) A given amount of colored light may be used and the time required for the eye to become completely exhausted or insensitive to this color may be determined. The difference in time required for this amount of fatigue to take place at the beginning and at the close of work will represent how much the retina has lost in its power to function for color. (2) The experiment need not be continued until complete exhaustion takes place. The amount of exhaustion that has taken place in a given interval of time can be measured. As before, this can be done at the beginning and at the close of work and the results can be compared to find out how much the retina has lost in power to give color sensation.

the consequence of three hours of work under the system of direct lighting, while in daylight practically no loss was shown.

In detail the test is as follows. When the observer is required to look at the test card for three minutes, the test objects, even when the eyes are fresh, are not seen clearly for the whole time. The muscular effort required to keep the eyes adjusted for clear vision cannot be sustained steadily for that length of time. The test objects are seen alternately as clear and blurred. The time they are seen clear and blurred is recorded on a rotating drum upon which a line registering seconds is also run. From this record the ratio of the time seen clear to the time seen blurred is determined. This ratio may be fairly taken as a measure of the efficiency of the eye at the time the test is taken. In applying the test to our problem the record is taken at the beginning and at the close of work, and the ratios of the time clear and the time blurred are compared for the two cases to determine how much the eye has lost in efficiency as a result of work. Two values were chosen for the distance at which the test card was placed from the eye: (a) the maximal distance at which the test objects could be seen clearly in the momentary judgment, and (b) a distance less than this. The latter distance was chosen because for the maximal distance towards the close of the test, even when the eyes were fresh, the value of the time blurred became, it was thought, excessively high. Results for the two distances, therefore, give probably a fairer expression of the loss in efficiency than for the one.

The problem dealing with loss of efficiency as the writer has conceived it presents two phases. We may investigate (a) whether the eye shows a loss of efficiency after three or four hours of work under a given lighting system, and (b) whether there is a progressive loss of efficiency in working several months or years under a given lighting system. Only the first part of this investigation has been attempted thus far in our work and it has been undertaken, not so much for the purpose of making an exhaustive study of loss of efficiency under a given set of conditions, as it has been to get a sensitive and practical method of detecting loss of efficiency. In order to determine whether the method we have described is practical and sufficiently sensitive for our purpose, tests should be made on a

large number of people under a wide range of lighting conditions. We have not as yet made tests under a wide range of lighting conditions. We have chosen rather to begin with three broad types of illumination now in general use; systems of direct lighting, systems of indirect lighting, and daylight. Types based upon the distribution of light have been selected because it has seemed to the writer, both from his own work and from a survey of the work done by others, that distribution or diffuseness of light is the most important factor we have yet to deal with in our search for conditions that give minimum loss of efficiency and maximum comfort in seeing. The quality of the light and its intensity at the source are already pretty well taken care of, apparently at least better taken care of in general practise, relative to their importance to the eye, than is distribution. A detailed report of our results will not be given in this paper. The following results selected as typical from a large number of observations are appended, however, to show how the efficiency of the eye as measured by the above test falls off as the result of three hours of work under a system of direct lighting as compared with daylight.

The tests were conducted in a room 30.5 feet (9.29 m.) long, 22.3 feet (6.797 m.) wide and 9.5 feet (2.895 m.) high. The daylight illumination came from six windows, all on one side provided with thin white curtains to secure the necessary control. The artificial lighting[9] was accomplished by means of two rows of fixtures of four fixtures each. Each row was 6 feet (1.828 m.) from the side wall and the fixtures were 6 feet apart. Each fixture was supplied with two 16 candle-power carbon lamps 29 inches (0.736 m.) from the ceiling with a white porcelain reflector 16 inches (0.406 m.) in diameter fastened directly above. The daylight tests were made at 9 A. M. and 12 M. Between these limiting times, the observer was required to read pages of type, uniform in size, printed upon paper of uniform texture of surface and of uniform reflecting power. The tests for the system

[9] This room gave the impression of being brilliantly lighted. The writer was amazed to find, however, that only 2.5 foot-candles of light were received on the test card placed about midway between two of the rows of lights and midway between two sets of fixtures. The walls and ceiling of the room were of plaster, natural finish, and the floor of dark tiling. Before our tests were taken, the walls and ceilings were painted white which nearly doubled the light received on the test card.

of direct lighting were taken at 7 P. M. and 10 P. M. During the interval intervening, the observer was required to read type of the same size and printed on the same paper as was used in the daylight work. The reading was done in each case at exactly the same spot in the room as at which the tests were made. The intensity of illumination was also in both cases made as nearly equal as it was possible to do by methods now available.[10] The two tests were always given on successive days but one. In order to guarantee that the observer's physical and optical condition should be as nearly the same for the two tests as it was possible to obtain, he was required to rest during the day immediately preceding each test. Since the li test has proven to be the more sensitive, results will be given for it alone in the following table. Column 1 of this table gives the time of day at which the work was done and the tests were made. Column 2 gives the type of test. Column 3 gives the distance of the test card from the eye. As stated earlier in the paper, two distances were used; one the maximum at which the test object could be seen clearly, the other a distance less than this. Division A of the table gives the results for the former distance; division B, for the latter. Columns 4 and 5 respectively, give the number of times the test object was seen clear and unclear. Column 6 gives the number of seconds in the three minutes that the test object was seen clear, and

[10] In order to equalize the intensity of illumination, a method of measurement is required. Two methods were used by us; photometry, and a more delicate method based upon the sensitivity of the peripheral retina to brightness contrast. In case of the former, a Sharp-Millar portable photometer was used. The light falling upon the test card was measured in foot-candles and was made equal for each type of lighting. Full details of the latter method will not be given here. As stated above it is based upon the extreme sensitivity of the peripheral retina to brightness contrast, especially to the induction by a white screen. To apply the method, some given illumination is taken as standard. The amount of black induced by a white campimeter screen upon a 15 mm. area of some medium gray, (*e. g.* Hering gray No. 14) at an excentricity of 25 deg. in the temporal meridian, is measured. This amount of contrast is taken as the index of that illumination. To duplicate the illumination at any succeeding time, the intensity is varied until the same amount of contrast is induced by the white screen on the gray at the 25 deg. point, for the same observer. This method was devised in the writer's laboratory and he has found by repeated trials that, although it is not so convenient for many of the purposes for which the photometric method is used, it is many times more sensitive than the traditional photometric method. The Sharp-Millar photometer, like other photometers, is insensitive for the determination of the illumination of a room by daylight. This is because the standard field illuminated by the tungsten lamp is deep orange in color, while the comparison field illuminated by daylight is clear white. This difference in color tone makes the judgment of brightness equality difficult to make and renders the instrument extremely insensitive for daylight work.

column 7 the number of seconds unclear. Column 8 gives the ratio of the total time clear to the total time unclear. This ratio as stated earlier in the paper expresses the efficiency of the eye for clear seeing for an interval of three minutes at the time at which the test was taken.

TABLE I.

Showing How the Eye Falls Off in Efficiency as the Result of Three Hours of Work under a System of Direct Lighting as Compared with Daylight. In Division A the Test Card is Put at the Maximal Distance at Which the Test Object Could be Seen Clearly; in Division B, at a Distance Less than This.[11]

Time of day	Test	Distance of card from eye cm.	Number of times clear	Number of times unclear	Total time clear sec.	Total time unclear sec.	Total time clear ÷ Total time unclear
A.							
9 A. M.	li	102	15	15	105.6	78.4	1.4
12 M.	li	102	15	14	103.1	76.9	1.33
7 P. M.	li	75	18	18	119.7	60.3	1.98
10 P. M.	li	75	15	15	55.4	124.6	0.44
B.							
9 A. M.	li	92	14	13	136.8	43.2	3.16
12 M.	li	92	12	12	134.9	45.1	2.99
7 P. M.	li	65	24	23	141.8	38.2	3.7
10 P. M.	li	65	17	17	75.5	104.5	0.72

[11] It will be noticed in the table that the ratio total time seen clear ÷ total time seen unclear is smaller for the test both at the beginning and at the close of work in division A where the maximal distance at which the test object could be seen was used, than in division B where a distance less than this was used. This is just what should be expected from the nature of the test. For it may be said that, within limits, the nearer the object is to the eye the greater is the proportion of time it should be seen clearly; and, conversely, the farther the object is from the eye the smaller is the proportion of time it should be seen clearly. It will also be noticed that the ratio is slightly larger when the tests are made under the system of direct lighting than when made under daylight. The explanation of this, too, is found in terms of the distances that were chosen for the test object. These distances, relative to the maximal distance, were chosen shorter for the artificial light than for daylight. This was done because of the large falling off in the ratio gotten for the test at the close of work under the artificial light. Had the first of the two distances used in these tests, for example, been chosen as near to the maximal distance for the artificial light as it was for daylight, the result of the test made at the close of work would have been that, after the first interval seen as clear, the test object would have been seen unclearly during the remainder of the test. At first glance one might be tempted to think that the difference in the scale of magnitude for the two ratios, is due to some inequality in the intensity of the illumination that was given by the two systems of lighting. It is obvious on reflection, however, that the intensity of illumination can have little or nothing to do with the scale of magnitude of these ratios. The intensity of the illumination influences the maximal distances at which the test object can be seen clearly but the scale of magnitude of the ratio, time clear to time unclear must depend primarily upon how near the distance chosen for the test object is to the maximal distance. (This principle, it is obvious, does not affect the comparison of the ratios obtained at the beginning and close of work under a given lighting system for the dis-

(*Continued on following page.*)

In order to give a typical representation in graphic form of the effect of three hours of work on the efficiency of the eye in daylight and under the system of direct lighting, estimated in terms of the test we have described, the results of the above table are given in the form of a curve. In constructing this curve the length of time of work is plotted along the abscissa and ratio of the time the test object is seen clear to the time unclear, is plotted along the ordinate. Each one of the large squares along the abscissa represents an hour of work, and along the ordinate an integer of the ratio. Figure I shows the result of division A and figure II for division B of the table. An inspection of these

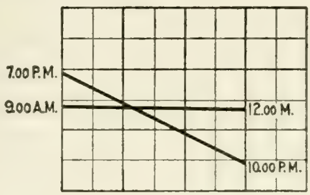


Fig. I.—Curve for division A of the table. Showing how the eye falls off in efficiency for three hours of work under a system of direct lighting as compared with daylight.

curves shows that the efficiency of the eye measured by the ratio of the time the test objects are seen clear to the time seen unclear, falls off rapidly for the system of direct lighting but scarcely at all for daylight.

Although it has been the purpose of this paper merely to out-

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tance, once it is chosen for that system, is kept the same or both tests). As further proof that the difference in the intensity of illumination had nothing whatever to do with this result, the intensity of illumination was carefully determined immediately before and after these tests and, if the readings showed any inconstancy in the illumination, the results were discarded and new tests were made. The above explanation should be borne in mind also in examining the curves plotted from the results of the table. The curve for division B of the table, for example, begins at a higher point on the ordinate than for division A; and the curve for the artificial illumination starts at a higher point than the curve for daylight.

It is scarcely necessary to point out that neither the scale of magnitude of ratio nor the point at which the curve starts is of any considerable consequence for our work. The important thing is not how large is the ratio at the beginning of work, but how much it falls off as the result of work. In fact the magnitude of ratio need not be taken into account at all any further than that it chances to be a coincident result of a condition that seems to render our test more sensitive. That is, our results seem to show that the ratio falls off more when the distance chosen for the test object is not too near the maximal distance. In future work, therefore, more care should be taken probably than was exercised in this preliminary study to choose the distances for the test object so that in case of each lighting system employed they shall sustain the same ratio to their corresponding maximal distances.

line and in part to demonstrate a set of tests, a word of discussion and interpretation of the results we have reported may not be out of place here. Since the visual acuity test (given under constant quality, intensity and distribution of light) is a test largely of the refractive mechanism of the eye and its muscular control and since the refractive mechanism could not have changed during three or four hours of work, the obvious indication of the above result is that the loss of efficiency sustained by the eye in these experiments is a loss in muscular efficiency. This conclusion is borne out also by the fact, stated earlier in the paper, that the direct tests of the efficiency of the retina, namely, the test for brightness and color sensitivity did not show conclusively any loss.[12] Moreover, the conlusion is in line with current conception. In current theory the retina is considered as a mechanism more or less compensating in its action, while

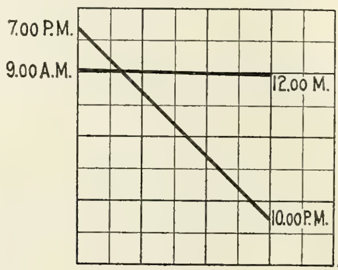

Fig. II.—Curve for division B of the table. Showing how the eye falls off in efficiency as the result of three hours of work under a system of direct lighting as compared with daylight.

the muscles of the eye are not so considered. The following reasons are suggested why the muscles of the eye giving both fixation and accommodation should be subjected to a greater strain by the system of direct lighting than by daylight. (1) The bright images of the electric bulbs falling on the peripheral retina which is in a perpetual state of darkness adaptation as compared with the central retina and is therefore extremely sensitive in its reaction to such intensive stimuli, sets up a reflex tendency for the eye to fixate them instead of the letters which the observer is engaged in reading. (2) Likewise, a strong reflex tendency to accommodate for these brilliant sources of light all at differ-

[12] This statement is also subject to the foot-note appended to the earlier statement.

ent distances from each other and from the lettered page, is set up. (3) These brilliant images falling upon a part of the retina that is not adapted to them causing as they do acute discomfort in a very short period of time,[13] doubtless induce spasmodic contractions of the muscles which both disturb the clearness of vision and greatly accentuate the fatiguing of the muscles. The net result of all these causes is excessive muscular strain which soon shows itself as a loss in power to do work. In the illumination of a room by daylight with a proper distribution of windows, the situation is quite different. The field of vision contains no bright sources of light to distract fixation and accommodation and to cause spasmodic muscular disturbances, due to the action of intensive light sources upon the dark adapted and sensitive peripheral retina. In daylight the light waves have suffered innumerable reflections and the light has become diffuse. The field of vision is uniformly illuminated. The illumination of the retina, therefore, falls off more or less uniformly from fovea to periphery as it should in order to permit of fixation and accommodation for a given object with the minimum amount of strain.

It is not our purpose to contend in this report that distribution is the only factor of importance in the illumination of a room. The intensity and the quality of the illumination must also be taken into consideration. To test the relative effect of these factors upon the working power of the eye, records would have to be taken when each was varied in turn and the other two maintained constant. In the results shown in the above tables the intensity alone was constant in the two cases. Both the quality and the distribution were different in the direct lighting system and the illumination by daylight. The difference in the results obtained will have, therefore, to be attributed both to

[13] There is no doubt in the writer's mind that the eye-discomfort experienced as the result of work under an unfavorable system of lighting is not by any means all muscular. The "sandiness" passing over into a stinging, stabbing pain which comes early in the experience of discomfort seems to be conjunctival. And while the retina itself is apparently insensitive to pain from mechanical stimulation, still when exposed to a source of light of a brilliancy to which it is not adapted, a painful reaction is produced which can scarcely be considered muscular. For example, after confinement for some time in a dark-room exposure to ordinary daylight is painful to the normal eye. That this is not entirely muscular can be shown by the fact that a similar reaction is experienced when the ciliary and iris muscles are paralyzed by atropine. The reaction is also experienced by aphakial subjects whose lenses have been so long removed that muscular atrophy must have taken place.

difference in the distribution and to difference in the quality of the illumination. In our tests comparative of the systems of direct and indirect lighting, the results of which will be reported in a later paper, clear tungsten lamps will be used in both cases. The intensity will be made the same and the quality of the light will be approximately the same. The distribution or diffusion alone will be different. Whatever difference in result we get in these two cases can, therefore, with reasonable certainty be attributed to the differences in the distribution of light.

With regard to the effect of varying the intensity of illumination, our results show nothing; with regard to the effect of varying quality, nothing in isolation; and with regard to distribution, we have data only for such differences as are found in the three types of illumination now in general use. In later work, however, the analysis along these lines will be completed. We hope on the laboratory side, to make a systematic study of the effect of wide ranges of variation of each of the factors in turn. It will be comparatively easy, for example, to keep the intensity and distribution constant and vary the quality, or to keep the quality and distribution constant and vary the intensity. We hope in addition, to supplement this work by testing the eyes of employees who work under a given lighting system for several hours a day, for evidences of a progressive loss of efficiency.

IV. A PRELIMINARY STUDY OF THE CAUSES OF DISCOMFORT.

In addition to studying the conditions that give us maximal efficiency, it is important to determine the lighting conditions and eye factors that cause discomfort. In fact, it might well be said that our problem in lighting at present is not so much how to see better as it is how to see with more comfort and with less damage to the general health on account of eye strain. Any comparative study of the conditions producing discomfort necessitates a means of estimating discomfort. It is obvious that the core of the experience of discomfort is either a sensation or a complex of sensations. As such, it should have a limen or threshold value just as other sensations have; and just as we are able in general to estimate sensitivity in terms of the threshold value, so should we in this case be able to use the threshold

value in estimating the eye's sensitivity or liability to discomfort under a given lighting condition. Threshold values are usually determined by finding how much energy or intensity of a given stimulus applied for a short interval of time is required to arouse a just noticeable sensation. This form of procedure, however, is not adapted to the needs of our problem. It is much better to reverse the process and find how long the eye has to be exposed to a stimulus of a given intensity to arouse just noticeable discomfort. Our limen, then, becomes a time limen, and is measured in units of time instead of in units of intensity. In order to determine whether the judgment of the limen of discomfort can be made with certainty and to test in general the feasibility of the method, the writer undertook to determine the comparative sensitivity of the eye to discomfort when the source of light was exposed in different parts of the field of vision. In order to carry out this investigation, a 16 candle-power lamp was attached to the arm of a perimeter in such a way that the end of the bulb was always directed towards the observer's eye. The arm of the perimeter could be shifted to any meridian in which it was desired to work, and the lamp could be moved at will along the arm. It was thus possible to expose the light at any point in the field of vision that was desired. Working in this way, we have investigated the effect of many types of variation of the distribution of the light in the visual field, and it is our purpose to extend the investigation as fast as possible to the variation of the other factors. Of the variations we have made in the distribution of the light in the field of vision, it will be necessary, however, in order to illustrate the general method of working, to describe only one, namely, the exposure of the source of light at different points in the field of vision for one eye when fixation and accommodation were taken for a far point.

In carrying out the investigation, the following precautions were observed. (a) It was found better to work in a room moderately illuminated by a source of light behind the observer and entirely concealed from him rather than in the dark. The intervals of dark-adaptation between exposures in the dark-room seemed to make the observer's eye too sensitive for our purpose. This was especially true for certain parts of the peripheral retina.

In becoming supersensitive there was a tendency to become erratically sensitive. (b) It was found that blinking serves as a variable factor for the relief of discomfort and that the amount of blinking must be made constant from test to test. This was accomplished by having the observer blink at equal intervals during the exposure, timing himself by the stroke of a metronome. The interval most natural and suitable for this purpose was determined for each observer separately. (c) All comparisons were planned in series. For example, if it were desired to compare the sensitivity of the temporal and nasal halves of the retina in a given meridian, the exposure was first made at a given point in one half and next at the corresponding point in the other half. This was to guarantee that the eye should be as nearly in the same condition with regard to progressive fatigue, etc., as was possible. Further to safeguard against error in this regard series were compared in which the exposures were repeated in the reverse order. (d) An interval of recovery was allowed between exposures. This interval had to be determined separately for each observer and often had to be made different for the same observer on different days. It was never changed, however, during the course of an experiment, the results of which were to be compared. (e) In order that the observer's head be held rigidly in position during the exposure, he was required to bite an impression of his teeth previously made and hardened in wax on a mouthboard. When an exposure was to be made, the fixation was taken, the light turned on, and a signal was given by the observer when a just noticeable discomfort was aroused, or, if it was desired, when the different stages of discomfort were reached. The judgment was found to present no especial difficulty, and the method, when properly applied, to provide a feasible means for comparing the sensitivity of the eye to discomfort under all the conditions to which we have been able thus far to extend its application. In actual practise the method also brings out an analysis of discomfort.

Discomfort seems to be a complex of three experiences, each of which develops at a different time. When the light is turned on, we have at once glare. This is a light sensation and though unpleasant has no painful elements. Next comes a conjunctival sensation

which begins with what is commonly called "sandiness" and soon passes over into a sharp, stinging, stabbing pain. Lastly there comes what is probably a muscular discomfort,—a hurting and aching in the ball of the eye which if the exposure is continued long enough seems to radiate to the socket and the surrounding regions of the face and head, the arch of the brow, the forehead, the temples, etc. Details will not be given here of the comparative sensitivity of different points of the retina to discomfort. It will be sufficient to say, that the periphery of the retina is more sensitive than the center; that the nasal half is in general more sensitive than the temporal half and the upper half than the lower half; and that in passing from the center to the periphery of the retina, the sensitivity is found first to increase then to decrease, becoming extremely little at the limits of the field of vision. In the horizontal meridians both on the temporal and nasal sides, maximal sensitivity is found around the 45 deg. point. In the vertical meridians, maximal sensitivity seems to be near the point 15 deg. below the horizontal. In a paper soon to be published, a detailed statement and explanation of these results will be given.

DISCUSSION.

Dr. H. E. Ives: This paper is well worth the while of professional psychologists to study; and it gives to the illuminating engineer results which are extremely valuable.

When the illuminating engineer has the problem of producing satisfactory results, he has two methods of doing so; first, the case system, in which he copies an illumination produced by nature or invention, which has proved satisfactory by experience; and he hopes to get the same result. But there are defects in this method; we are very apt to follow the example of the Chinese who made motors by copying the imported ones even down to the color of the paint on the casings and the scratches on the paint We may do equally foolish things by slavish copying. That is inherent in the case system. Up to recently some of us have been of the opinion that even with the defects of this case system we could apply it to advantage, for instance by studying how nature produces her lighting schemes. But in order to make any great

progress we must deviate from what exists; we must experiment and invent. This necessitates some means of testing our results and this process of experiment and test constitute the second procedure. Our Society has lately been interested in the physiological side of illumination, but has been sadly handicapped by the lack of significant tests—we have been dependent practically on laboriously acquired experience. One great object in adopting a method of measurement is the saving of time. For instance, suppose our only means of measuring voltage was by the duration of physiological disturbances following an electric shock. In order to duplicate a voltage which gives a shock whose after effects last a day, we would require weeks or months of toil, because of the time necessary to wait for the results of each experiment. Suppose the first time we secured the desired voltage we had an instrument known as a "voltmeter;" it would only take a minute to determine that voltage. We want something for measuring the effect of lighting systems which will enable us to get results with a speed comparable with that of a voltmeter.

Various methods of test have been proposed and Dr. Ferree has gone over all of these. He arrives at a conclusion which I think it behooves us all to observe; namely, that these tests will show what he calls "the general level or scale of visual efficiency," but they are practically useless as tests of the *loss* of visual efficiency.

Here is a sentence which means a great deal "Just as a runner may, under the spur of his will, equal in the last lap of his course the highest speed he has attained at any other point in the course, so may the flagging muscles of the eye be whipped up to their normal power long enough to make the judgment required by the visual acuity test."

Dr. Ferree here gives us the benefit of his point of view and experience in these matters. In this paper he has recognized the inefficiency of the methods now used. He realizes that we want a test of the *loss* of visual efficiency. The eye may respond momentarily, like the tired runner, and see the object as distinctly as before, but we know that it is not as efficient. Dr. Ferree has devised a test in which is introduced a time element. The observer views a visual acuity test object. When the

limit of visibility is found the observer is not allowed to rest, because he will again after an interval get just as good results as at first; instead he presses a key as long as the detail is clear; then when the tired muscles flag and the object blurs, the finger on the key is removed. At first it appears easy to see the detail clearly, but pretty soon it is not so easy and one does not distinguish the chart so well. Very soon it becomes necessary to take the finger off the key. Intervals of clear and blurred vision alternate and at the end we have a ratio of the time the chart is distinguishable to the time when it is not.

Dr. Ferree has tried out daylight and a direct artificial lighting system and we have here for the first time the results of that test. They show what many of us have been sure of; that daylight does not decrease the efficiency nearly as much as artificial lighting. On the fourteenth and fifteenth pages are two charts showing by straight lines the falling off in efficiency which occurs under artificial lighting as compared to daylight. Personally, I think we should say "Eureka!"

I hope Dr. Ferree will proceed to standardize these tests and tell us the best working distances and one thing and another. As he is not here, I have tried to bring out the most important points. He has given us a most valuable contribution, and I hope before long we will be in a position to settle these questions of light and dark walls by this method of test and not by "Kilkennycat" discussion, which brings us nowhere.

I think we should do our best to aid Dr. Ferree to develop this method of test to give us what now we can get only by experience. I am aware that I have not done this paper justice, but I want to express my appreciation of his work.

Mr. C. O. Bond: The American Medical Association is a body whose conclusions as to the harmful or beneficial effects of any types of illuminating installations will carry considerable weight. They have discussed time after time how they were to make the tests, and this paper has grown out of Dr. Ferree's experiments, in the hope of placing in the hands of that Committee means of making the tests. We are extremely fortunate in having the first public report of this method. The method is under advisement by the Committee and I was present at one of their meetings when Dr. Ferree brought a set of this apparatus

to Philadelphia and they made a test of it. Two or three of the doctors present were very much impressed with it. I think, even if it does not succeed as it now stands, perhaps here is the germ of the best possible method of test.

DR. C. E. FERREE (communicated in reply): I can express only great appreciation of the interest that the men who have preceded me have taken in our work. The problem is extremely interesting to me and I hope we have here a vulnerable point of attack. Once we have procured a successful method of measuring the effect of different lighting systems on the eye, a broad field of application opens out before us. We not only can find out what are the favorable and what are the unfavorable features in a lighting system, but we can no doubt, as may be inferred from Dr. Ives' discussion, test out and perfect a lighting system, so far as its effect on the eye is concerned, before we put it on the market. This latter point is a good one, I think, and I thank Dr. Ives for the suggestion.* I feel that Dr. Ives' perspective and practical grasp of the situation is a distinct contribution to the paper.

We are very much handicapped at present for funds by means of which to carry on this work. In the first place apparatus and models of lighting systems are required for the work on the laboratory side. Trained assistants are also needed to help out with the details of the work. Further, to verify and enlarge the work done in miniature in the laboratory, we should test the eyes of employees working under established lighting systems and in the surroundings in which these systems have to operate. All of this takes time and money, also entrance into commercial concerns. In all of these regards we need the help and influence of the Illuminating Engineering Society.

This work, I suppose, could be done spontaneously and sporadically here and there as the insight and inclination of various men may direct. But in the beginning, at least, I do not think it should be scattered. Until launched and safely moving, it should be done under common supervison.

* The general idea that over and above its application to abstract investigation the test may have an application in the daily work of the lighting engineer has come to the writer by suggestion from the engineers themselves. Mr. Cravath, for example, has recently pointed out that the test should be of advantage in making the actual installation of a lighting system. The writer would suggest in addition that it may further be of service in determining the effect of different kinds of type and paper on the efficiency of the eye; also the effect of different kinds of desk lighting, etc. In short, it is obvious that the usefulness of such a test is limited along these lines only by its sensitivity.

TRANSACTIONS
OF THE
Illuminating Engineering Society

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Index for Volume VII.

The index for Volume VII (1912) of the TRANSACTIONS is mailed with this number.

Council Notes.

The council held a regular meeting in the general offices of the society, 29 West 39th Street, New York, February 14, 1913. Those in attendance were: Preston S. Millar, president; George S. Barrows, Louis Bell, C. O. Bond, J. R. Cravath, Joseph D. Israel, general secretary; V. R. Lansingh, Norman Macbeth, L. B. Marks, treasurer; W. Cullen Morris, C. J. Russell and W. J. Serrill.

A monthly report on the membership and the receipts and expenses was received from the general secretary. The number of members, counting the applications and resignations presented at the meeting, was said to total 1,325.

Eleven applicants were elected members. Their names appear on another page of this number.

Reports on section activities were received from Vice-presidents J. R. Cravath (Chicago), Howard S. Evans (Pittsburgh), J. W. Cowles (Boston), W. J. Serrill (Philadelphia).

A tentative report on proposed work was received from the chairman of the section development committee. It was stated that the first meeting of the committee was to be held February 15 and that a more definite report would be presented later.

An oral report was received from the papers committee. The arrangements for the papers program of the next convention were discussed briefly. It was said that it might be well to arrange the next convention program somewhat as follows: the first day to be devoted to society affairs; the second day to the presentation of technical papers; the third day to the reading of papers of a commercial character; and the last day to a series of lectures and talks on the architectural and decorative aspects of illuminating engineering. It was understood that a definite report would be received from the papers committee at the March meeting of the council.

In a report received from the committee on editing and publication it was stated that beginning with the 1913 issue of the TRANSACTIONS an inexpensive mat surface paper for the ordinary text matter and line illustrations and a coated paper for the photographic reproductions would be used; each issue of the TRANSACTIONS will be printed in two parts; Part I will be devoted to council and section notes and news items; Part II will include papers, discussions and important committee reports. The committee also asked for an appropriation of $20.00 to print two or three hundred copies of a guide

setting forth the character and style of papers for presentation at meetings of the society and for publication in the TRANSACTIONS. The appropriation was authorized.

Progress reports were received from the sustaining membership committee, the committee on new membership and the committee on reciprocal relations with other societies.

A tentative report from the committee on glare from reflecting surfaces outlined the work of the committee for the present year. In its work the committee will give special attention to school officials and school book companies. The co-operation of other societies will be solicited. Information regarding paper making and the publishing art will be continually sought. Encouragement will be given to manufacturers to produce a dull finished paper which will reproduce half-tones satisfactorily. The committee also believes that it is possible to collect sufficient data regarding the use of blackboards, polished desk tops, glazed paper, etc., to form a paper of sufficient value to find a place on the program of the next convention of the society. Briefly speaking, the committee will make every effort toward the elimination of polished surfaces, but for the present it will confine its efforts to the public schools.

The finance committee reported that it had approved for payment vouchers Nos. 1170 and 1173, inclusive, and 1175 to 1209, inclusive, aggregating $759.02.

The factory lighting legislation committee reported that the recommendations which it had submitted to the New York Factory Investigating Commission pertaining to bill No. 18 having to do with the lighting of factories and work rooms had been incorporated in the revised bill of the commission.

An oral report was received from the committee on illumination primer. The committee asked that the council authorize the publication of a large edition of the primer to fill any orders that may be received, and that permission be given to make a few changes in the primer. The council authorized the committee to make such changes as it may deem necessary, and the printing of such editions of the primer as may be required from time to time. It was understood that these editions would be gotten out by the general office.

A report was received from Mr. C. A. Littlefield, chairman of the committee of arrangements for the 1913 annual meeting. It was resolved to extend to Mr. Littlefield and the members of his committee, on behalf of the society, a very hearty vote of thanks for the excellent and successful meeting and dinner which they had arranged.

Upon receipt of a report from Mr. V. R. Lansingh, chairman of a preliminary committee, it was resolved that the president appoint a committee to foster the establishment, maintenance and development of courses in illuminating engineering in colleges and universities. The president appointed the following committee, which is to be known as the committee on collegiate education: V. R. Lansingh, chairman; Prof. Henry B. Dates, secretary; Dr. H. E. Ives.

The president was requested to appoint a committee to consider and report to the council upon the advisability (1) of holding the 1915 annual convention in San Francisco, and (2) of endeavoring to arrange for that time and place a joint meeting of the several illuminating engineering societies or a meeting of the proposed International Commission on Illumination, or both.

The president was also requested to appoint a committee on popular lectures, said committee to be asked to promulgate a plan for preparation of popular lectures on various classes of lighting installations (as factory, store, residence, etc.) and, after plan has been approved by the council, to undertake the preparation of such lectures, either directly or through sub-committees.

It was resolved that the council of the Illuminating Engineering Society takes pleasure in accepting the invitation of the American Gas Institute to join in a session on illumination at Richmond Va., on October 16, 1913.

New Members.

The following applicants were elected members of the society at a meeting of the council held February 14, 1913:

Burrows, S. B.
Public Service Electric Co., Newark, N. J.

Clinch, Edward S., Jr.
Lord Electric Co., 105 West 40th Street, New York, N. Y.

Frey, Arthur C.
Cadet Engineer, United Gas Improvement Co., Broad and Arch Streets, Philadelphia, Pa.

Gudge, B. J.
Electrical Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Higgins, Warren Sneden.
Instructor in Electrical Engineering, Lafayette College, Easton, Pa.

Horner, Harry Archer.
Electrical Engineer, New York Shipbuilding Co., Camden, N. J.

Kelsey, Fenton P.
Vice-President and Editor, *Gas Record*, Chicago, Ill.

Malia, James P.
Chief Electrician, Armour & Co., Union Stock Yards, Chicago, Ill.

McCulloch, Fred. H.
Treasurer, Electric Supply & Fixture Co., 123 East Washington Street, Fort Wayne, Ind.

Skinner. Ross H.
Assistant to General Contracting Agent, Consolidated Gas Co., 435 Sixth Avenue, Pittsburgh, Pa.

Stafford, Raymond W.
Assistant Foreman, The New York Edison Company, 117 West 39th Street, New York City.

Section Activities.

CHICAGO SECTION

A joint meeting of engineering, architectural and ophthalmological societies was held at the Republican House in Milwaukee, February 22, 1913. The following societies participated:

Chicago Section of the Illuminating Engineering Society.

Engineering Society of Wisconsin.

Milwaukee Company Section of the National Electric Light Association.

Milwaukee Electrical League.

Milwaukee Engineering Society.

Milwaukee Oto-ophthalmic Club.

Milwaukee Section of the American Chemical Society.

Milwaukee Section of the American Institute of Electrical Engineers.

Madison Section of the American Institute of Electrical Engineers.

Wisconsin Chapter of the American Institute of Architects.

The program presented was as follows:

"Light and Art," by Mr. M. Luckiesh, engineer, National Electric Lamp Association, Cleveland, O.

Discussion of "Ocular Comfort and its Relation to Glare from Reflecting

Surfaces," by Mr. F. A. Vaughn, consulting engineer, and Dr. Nelson M. Black, ophthalmologist, Milwaukee, Wis.

"A Photometer Screen for Use in Tests of Street Illumination," by Prof. Arthur H. Ford, State University of Iowa, Iowa City.

"The Influence of Colored Surroundings on the Color of the Useful Light," by Mr. M. Luckiesh, engineer, National Electric Lamp Association, Cleveland, O.

These papers and discussions will appear in later issues of the TRANSACTIONS. The meeting was well attended, some 30 or 40 Chicago men, besides members from Madison, Milwaukee and other Wisconsin and Michigan points being present.

NEW ENGLAND SECTION

The New England section held a joint meeting with the Boston section of the American Institute of Electrical Engineers in the auditorium of the Boston Edison Building, 39 Boylston Street, Boston, February 17, 1913. The following papers were read:

"Street Lighting with Ornamental Luminous Arc Lamps" by C. A. B. Halvorson, Jr., of the General Electric Company, West Lynn, Mass.

"The Theory of Mercury-Vapor Apparatus" by P. H. Thomas, consulting engineer, New York.

"Flame Carbon Arc Lamps" by W. A. Darrah of the Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.

The first two of these papers appear in this issue of the TRANSACTIONS. The last one will be published later.

NEW YORK SECTION

A joint meeting of the New York section of the I. E. S. and the Municipal Art Society was held in the National Arts Club, 119 East 19th Street, New York, February 12, 1913. The topic of the evening was "Municipal Lighting." Addresses were made by C. F. Lacombe, chief engineer of the Department of Water Supply, Gas and Electricity of New York City; Charles Roland Lamb, ecclesiastical architect; William Wentz, vice-president, O. J. Gude Company, and Arthur Williams, general inspector, The New York Edison Company. A dinner preceded the meeting and was attended by guests and members of both the club and the society.

The program of meetings for the remainder of the season is as follows:

March 13—Joint meeting with the American Society of Mechanical Engineers in the United Engineering Societies Building, 29 West 39th Street, New York. Mr. Ward Harrison of the National Electric Lamp Association will present a paper on "Industrial Lighting."

April 9—This meeting will probably be held in the United Engineering Societies Building. Mr. M. Luckiesh of the National Electric Lamp Association will present a paper on "Light and Art." A paper on "Phosphorescence and Fluorescence" is also scheduled. This meeting should be an unusually interesting one.

May 8—A talk on theater lighting by Mr. Bassett Jones, Jr., at the Clymer Street Theater, Brooklyn. During the past year Mr. Jones has conducted a great deal of experimental work in theater illumination particularly in the production of stage effects. The members of the New York chapter of the American Institute of Architects will be invited to attend this meeting. Admission will be by card.

June 8—It is planned to have a joint meeting and outing of all the engineering societies in New York.

PHILADELPHIA SECTION

The February meeting of the Philadelphia section of the Illuminating Engineering Society was held on February 21, 1913, at the Engineers' Club, 1317 Spruce Street, Philadelphia. At the dinner preceding the meeting, which was held in the dining-room of the Engineers' Club, 46 members and guests were present. One hundred and seventy-five members including a number of architects and ophthalmologists were present.

Mr. P. S. Millar, president of the society, presented a paper on "Some Phases of .the Illumination of Interiors." The subject was discussed by Messrs. Perot, Bond, Regar, Hare, Dickey, Swanfeld, Israel, Prof. Hoadley and Dr. Crampton.

PITTSBURGH SECTION

A meeting of the Pittsburgh section was held in the hall of the Engineers' Society of Western Pennsylvania, Oliver Building Pittsburgh, February 21, 1913. A paper on gas illumination by Mr. S. B. Stewart of the Consolidated Gas Company was presented.

The program of meetings for the rest of the season is as follows:

March—"Moving Picture Lanterns from the Central Station Point of View" by J. F. Martin.

April—"Railroad Car Lighting" by J. L. Minick.

May—"Physiological Aspects of Illumination" by W. E. Reed.

June—Announcement will be made later.

TRANSACTIONS

OF THE

Illuminating Engineering Society

FEBRUARY, 1913

PART II

Papers, Discussions and Reports

[FEBRUARY, 1913]

CONTENTS -- PART II

THE INFLUENCE OF COLORED SURROUNDINGS ON THE COLOR OF THE USEFUL LIGHT.*

BY M. LUCKIESH.

Synopsis: In the course of the investigation reported in this paper, theoretical computations and also actual colorimeter measurements were made to determine the magnitude of the influence of colored surroundings on the color of the useful light. Much attention has heretofore been given to the color value of illuminants, when after all the color value of the useful light is perhaps of greater interest to the user. It was suspected that especially in indirect lighting the colored walls and ceiling, even though nearly white, would effect appreciable color changes in the incident light. Calculations given in this paper show that only a moderately yellow paper is required to change the color of tungsten light to that of a carbon filament lamp. Both direct and indirect lighting were considered in the computations; the results obtained are plotted in several ways.

A miniature room was fitted with a tungsten unit in the middle of the ceiling. The walls and ceiling were covered with combinations of green, yellow, and white paper. Colorimeter readings were made with direct and indirect lighting. These are shown in a table and in a color-triangle. Reflection coefficients are briefly discussed and measurements presented for several papers illuminated by various illuminants. These measurements were made with a flicker photometer.

The color value of illuminants has been a subject of considerable interest during the last few years. The light from the modern metallic filament lamps has been lauded by many because of its nearer approach to daylight than many of the other common illuminants, while a few have expressed favor for the "softer" yellow light of the carbon filament lamp. Relatively the color values of common illuminants differ considerably. When these illuminants are used amid colored surroundings one is led to suspect that considerable change in the color value of the useful light might take place especially with indirect and semi-indirect lighting. Of course great color changes can be effected by using colored reflecting surfaces, the amount of alteration in color depending upon conditions. For instance, there is no theoretical reason why the light from ordinary illuminants cannot be altered by reflection from colored surfaces to accurately match "average

[1] A paper read at a meeting of the Chicago section of the Illuminating Engineering Society, in Milwaukee, Wis., February 22, 1913.

daylight." In nature considerable change takes place in the color of sunlight on being reflected from the earth and especially from green foliage. This has been shown by noting in this reflected light the absorption bands of chlorophyl which is the green coloring matter of foliage. Measurements at sea or over a sufficiently large snow field in winter do not show these peculiarities. Mr. G. S. Merrill[1] has measured the color values of daylight on the working plane in a room after part of it had been reflected from the colored surroundings. The interior measurements were made on clear and cloudy days. They showed considerable alteration in the color of outdoor average daylight.

In direct artificial lighting much less light reaches the working plane via the walls and ceiling than in semi-indirect or indirect lighting. Obviously in the latter system all the light which is diffusely reflected by colored walls or ceilings is altered in color. When the reflection coefficient is small the influence of the colored paper is small, especially in direct lighting owing to the small amount of the colored light which is added to the direct light. In such cases only about two reflections need be considered, as there is little light remaining unabsorbed after it has suffered two reflections. When the reflection coefficient of the surroundings is large many more reflections must be taken into account as will be shown later.

Assume an illuminant radiating equal amounts of monochromatic red, green and blue light which might be represented relatively as

R	G	B
100	100	100

Further assume that this light source is placed in the center of an Ulbricht sphere, the walls of which are covered with perfectly diffusing green paper. The reflection coefficients of this paper for the particular illuminant are assumed to be

R	G	B
25.2	47.2	27.6

The light received by the green paper is reflected an infinite number of times. If the walls of the sphere are temporarily sup-

[1] *Proc.* American Institute of Electrical Engineers, p. 1726, 1910.

posed to be white and if N is the reflection coefficient of the paper then the total light falling on the walls will be

$$Q = Q' + NQ' + N^2Q' + N^3Q' + \ldots\ldots = \frac{Q'}{1 - N} \qquad (1)$$

where Q = total light falling on the walls,
Q' = direct light from the light source falling on the walls.

Color values of a paper are determined by measuring the color value of the light after it has suffered one reflection. A reflection coefficient of 33⅓ per cent. was assumed for the green paper for this particular illuminant. The coefficient of reflection of the paper can vary between wide limits without any change in the color values.

Based on the foregoing assumptions, the reflection coefficient of this paper for the monochromatic red light is 25.2 per cent. of the original 100 units; 47.2 per cent. of the total 100 units of green light; 27.6 per cent. for the total 100 units of blue light. For this case the total red, green and blue components in the light incident on the wall paper after an infinite number of reflections will be

$$Q_R = Q'_R + N_RQ'_R + N_R^2Q'_R + N_R^3Q'_R + \ldots = \frac{Q'_R}{1 - N_R} \qquad (2)$$

$$Q_G = Q'_G + N_GQ'_G + N_G^2Q'_G + N_G^3Q'_G + \ldots = \frac{Q'_G}{1 - N_G} \qquad (3)$$

$$Q_B = Q'_B + N_BQ'_B + N_B^2Q'_B + N_B^3Q'_B + \ldots = \frac{Q'_B}{1 - N_B} \qquad (4)$$

and

$$Q = Q_R + Q_G + Q_B = \text{total light on walls} \qquad (5)$$

$$Q' = Q'_R + Q'_G + Q'_B = \text{total direct light on walls} \qquad (6)$$

N_R, N_G, N_B are respectively the reflection coefficients for the monochromatic red, green and blue lights.

$N_RQ'_R$, $N_GQ'_G$, $N_BQ'_B$ are the color values of the wall paper as determined by the colorimeter under the light Q'.

It is interesting to make some calculations in this particular case.

TABLE I.—COMPUTATIONS ACCORDING TO EQUATIONS (2), (3) AND (4), SHOWING THE CHANGES PRODUCED IN THE LIGHT FROM A SPECIAL "WHITE SOURCE" BY SUCCESSIVE REFLECTIONS FROM A CERTAIN GREEN PAPER *a*.

The term in equations (2), (3) and (4)	Values			Values reduced for plotting in color triangle			
	R	G	B	R	G	B	
Q'	100	100	100	33.3	33.3	33.3	a
NQ'....	25.20	47.20	27.60	25.2	47.2	27.6	b
N^2Q'....	6.35	22.30	7.62	17.5	61.5	21.0	c
N^3Q'....	1.60	10.45	2.10	11.3	73.9	14.8	d
N^4Q'....	0.40	4.93	0.58	6.8	83.4	4.8	e
N^5Q'....	0.10	2.33	0.16	3.8	90.0	6.2	f
N^6Q'....	0.03	1.10	0.04	2.6	94.0	3.4	g
N^7Q'....		0.52	0.01				
N^8Q'....		0.25					
N^9Q'....		0.12					

The reduced values *a, b, c,* etc., are plotted in fig. 1. Theoretically these values should be plotted in the color pyramid as they

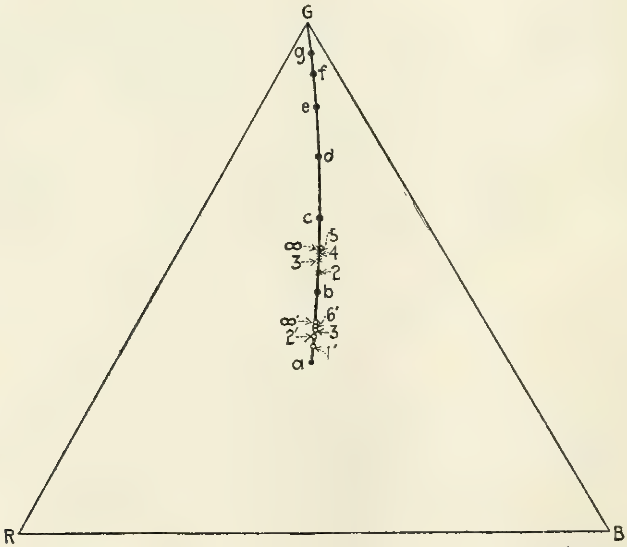


Fig. 1.—Theoretical computations of the changes taking place in the color of light under various conditions and after undergoing various reflections are plotted in trilinear coordinates.

are of unequal luminosity but for clearness they are plotted in one plane—the color triangle—which method shows their rela-

tive positions. It will be noted how the color of the light approaches saturated green as the number of reflections increases. In fig. 2 are plotted the actual luminosity values of the red, green and blue components in the light after it has undergone various reflections. The full lines represent the magnitude of the components when the reflection coefficient of the paper is 33⅓ per cent. for the illuminant used. The dotted lines show the rapid decrease in the values with a paper of 10 per cent. reflection coefficient as compared with one of 33⅓ per cent. coefficient. This data of course is not truly represented by a curve because there

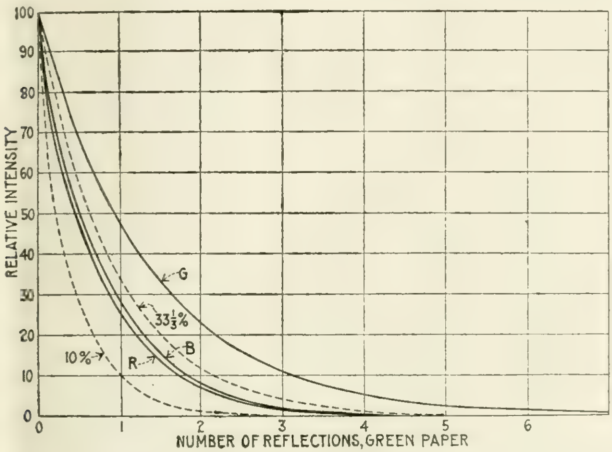


Fig. 2.—The percentage of the original light remaining after it has suffered various reflections.

cannot be fractional parts of a reflection. The various points corresponding to different reflections are connected by the curves merely as a graphical means of representing the data. In fig. 3 are plotted the relative amounts of the red, green and blue components in the light after it has suffered various reflections. The sum of the ordinates at any particular reflection equals 100 per cent. Here the rapid approach toward a pure green is shown after the light has undergone several reflections.

Turning again to fig. 1 and Table I some more interesting calculations are possible. First let us discard the direct light from the calculations. Adding the light of the first and second reflections in columns 2, 3 and 4 and making the sum of the three

components equal to 100 we have the quality of the light reflected once from the paper but diluted with the light of the second reflection. This latter amount is small but more greenish in color. This value is plotted with a cross and numbered 2, which indicates the sum of two reflections. The sum of three, four and five reflections are also plotted as crosses and labeled consistently. The final color of the light after undergoing an infinite number of reflections (and absorptions) is found by summating the series in equations 2, 3 and 4 and subtracting in each case the direct component. This value for indirect lighting might be

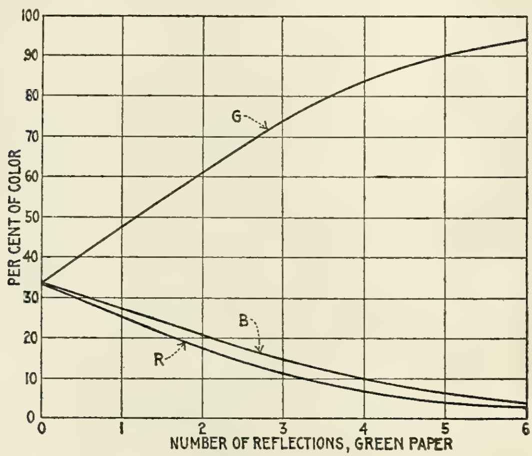


Fig. 3.—The percentage of the three components in the light after undergoing various reflections from green paper.

found by measuring the color of a white surface screened from the light source. It is plotted as ∞.

Next the effect of adding a constant amount of direct light Q' to the reflected light is shown by the circles. Circle number $1'$ shows the color of the direct light as diluted by the first reflection. Circles $2'$, $3'$, $4'$, $6'$ indicate the change in the color of the total light as more reflections are considered. The color of the total light after it has undergone an infinite number of reflections is found by summating each series in equations 2, 3 and 4, and making the sum of the three values equal to 100. It is plotted as ∞'.

After purely theoretical computations made only for the purpose of showing the order of magnitude of the possible color changes, it becomes of interest to make some observations with an Ives colorimeter and in a room papered with various colored wall papers. With actual colored papers as used on walls there is more or less specular reflection. The light which is specularly reflected does not necessarily undergo the same change in its color as in the case of diffuse reflection. This fact must be considered when using the colorimeter for determining the color of papers and other things. If the paper is placed at such an angle as to regularly reflect the light from its illuminant into the colorimeter obviously the true color of the paper will not be obtained. Mere observation indicates that more likely the colorimeter readings will more nearly represent the color of the illuminant than that of the paper.

It is impractical to use an actual room in these experiments owing to the great amount of light required for the colorimeter readings and also the large surfaces which must be re-papered. Besides the results would only hold for that particular room, wall paper, etc. This of course is true with any arrangement of apparatus. The object of these measurements was merely to show the possible magnitude of the color changes in the illuminant after it had suffered various reflections and had reached the working plane. A cubical box, four feet on a side, was arranged with a single fixture in the center of the ceiling. The light source was a 500-watt tungsten lamp. This source was used directly and indirectly. With the direct system no reflector was used, of course permitting considerably more than the usual percentage of light flux to reach the walls and ceiling. Green, yellow and white papers were used. The green and yellow papers were selected from regular wall paper stock and were quite unsaturated colors. The white paper used was blotting paper. All colorimeter readings were made with the photometric field of constant brightness. The colorimeter readings under various conditions are shown in Table II. It will be noted that the readings for the tungsten lamp are shown as being equal for the red, green and blue. This course was considered legitimate for several reasons. First it was found impossible to make the readings comparable with data

heretofore published by others without entailing a vast amount of work which was considered unwarranted owing to the fact that the cases are not general. Further the chief object was to show only the order of magnitude of the color-changes compared with the magnitude of the color difference between the carbon and tungsten incandescent lamps. The results are plotted in trilinear co-ordinates in fig. 4. It is interesting to note that 4, 5, 6, 7 show a gradual change from yellow toward "white" as would be expected in going from indirectly lighted yellow walls and ceiling to a white ceiling and direct lighting. These results are consistent with the theoretical computations in the first part of the paper. The color values of the carbon lamps (shown as 2 and 3 in Table II) are relative to the tungsten lamp and are given in order to illustrate the magnitude of the change in the color of

TABLE II.—Colorimeter Measurements in a Miniature Room under Various Conditions.

		R	G	B
1	Tungsten lamp	33.3	33.3	33.3
2	Carbon lamp, 3.1 watts per candle	38.7	34.7	26.6
3	Carbon lamp, 4 watts per candle	43.0	33.7	23.3
4	Yellow walls and ceiling, indirect	53.1	37.0	9.9
5	Yellow walls and ceiling, direct	47.6	35.7	16.7
6	Yellow walls and white ceiling, indirect	43.2	35.5	21.3
7	Yellow walls and white ceiling, direct	42.1	35.3	27.6
8	Yellow paper	43.6	38.4	18.0
9	Green paper	34.5	39.8	25.7
10	Green ceiling and green walls, indirect	35.9	43.6	17.5
11	Green ceiling and green walls, direct	36.3	37.8	25.9
12	Green walls and yellow ceiling, indirect	48.2	42.6	9.2
13	Green walls and yellow ceiling, direct	39.8	39.6	20.6
14	Green walls and white ceiling, indirect	36.6	34.1	29.3
15	Green walls and white ceiling, direct	35.2	34.6	30.2

the tungsten light due to colored surroundings. The color values of the yellow and green papers used in the box are given at 8 and 9 and in the table. These were determined with the colorimeter and show the color of the tungsten light after being once reflected from the paper.

An instrument for observing the change in the color of incandescent lamp light due to colored surroundings is easily made. A box 16 inches long and 4 inches square contains a lamp of the same type and voltage as used in the room in question. This

lamp is fastened in one end of the box and illuminates a piece of opal glass. This portion of the box should have a *white* coating on its interior walls. Variation in the brightness of the glass is obtained by means of a diaphragm. In an adjacent compartment is a mirror inclined at 45 deg. to the vertical. Above this is a ground opal glass which receives the light just as it is received on the working plane. By means of the mirror this glass is seen adjacent to the glass illuminated by the electric lamp. When a brightness match is made the change in the color of the illuminant is observable. Such a box was made and observable changes in the color of the illuminant due to colored surroundings

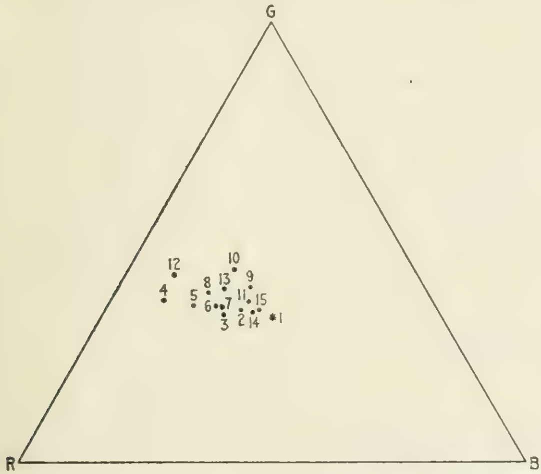


Fig. 4.—Results obtained in a small room (plotted from Table II.).

were noted even in extreme cases of direct lighting. A modification can be made by using in place of the electric lamp a vertical tube which admits light to the first opal glass from the illuminant only in much the same manner as the Sharp-Miller photometer is used for candle-power measurements. This latter arrangement could be used with all kinds of illuminants, but would be useless in indirect lighting where perhaps the greatest color changes are found.

Although it is well known that the coefficient of reflection of a surface is not the same for all illuminants unless that surface is white, it may not be out of place to discuss reflection coefficients

briefly. With the ever increasing diversity of types of light sources and refinement of illuminating engineering procedure it may soon become desirable when giving reflection coefficients to also include in the statement the light source for which the coefficient was determined. To illustrate this point some relative reflection coefficients of various colored papers of high saturation are given in Table III. These were determined only relatively by measuring the relative brightnesses in a fixed direction while the specimen was illuminated successively by various illuminants at hand. The brightness measurements were made by means of a flicker photometer, the comparison standard being a white matt surface (magnesia) illuminated by means of a tungsten lamp.

TABLE III.—RELATIVE BRIGHTNESS OF VARIOUS PAPERS ILLUMINATED FROM DIFFERENT SOURCES.

	Color of paper				
Illuminant	White %	Red %	Yellow %	Green %	Blue %
Tungsten (Ruby) lamp	100	84	96	23	9
Mercury-vapor lamp	100	8	95	33	14
Tungsten lamp	100	36	91	26	11
Carbon, 4 watts per candle lamp	100	41	94	27	11

The papers were all viewed at the same angle and likewise illuminated from the same direction. Specular reflection was carefully avoided. The results for the carbon and tungsten lamps are the averages of a great many determinations.

SUMMARY.

Based upon purely theoretical considerations, computations are made showing the influence of colored surroundings on the color of the useful light. The color of the multi-reflected light is shown with and without being diluted by direct light. The intensity and color value of the light is calculated for various reflections. They were roughly verified by actual measurements of the color changes of light in a large box, the interior of which was covered with various combinations of white, yellow, and green papers. The results obtained were consistent with the previous computations.

The actual change in the reflection coefficients of various colored papers when illuminated by various commercial light sources is shown.

The writer is indebted to Mr. Leonard Krill for assistance in the experimental work.

DISCUSSION.

Dr. Herbert E. Ives (communicated): The paper by Mr. Luckiesh on "The Influence of Colored Surroundings" is not, I think, as clear as it should be on several points in color measurement.

The first part of the paper contains what are called "purely theoretical computations" on color changes to be expected by multiple reflection of light from colored surfaces. As a basis for these are taken certain "colorimeter readings." As a matter of fact the computations are not for a colorimeter at all, but for a spectrophotometer making measurements at three wave-lengths. Instead of calling these "colorimeter readings" they should be called "intensities on an arbitrary scale."

Taking up this matter in detail one finds on the second page that a special illuminant is assumed, radiating three monochromatic radiations—red, green and blue. On the third page the definition of the quantities $N_R Q'_R$, etc., which follows the calculations shows that the "color values" are supposed to be obtained by the colorimeter under these three monochromatic lights. Another limitation which is tacitly made is that the special tri-chromatic light shall be composed of exactly the wave-lengths used in the colorimeter.

The complete assumption is then for a tri-color illuminant of the same constituents as the colorimeter primaries, and that the colorimeter values of the colored surfaces are to be obtained under this illuminant. This means nothing more nor less than that the colorimeter has been ingeniously transformed into a photometer for making measurements under the three special colors of light—in other words, into a form of spectrophotometer.

The essential characteristic of a colorimeter, as commonly understood, is that it measures colors of any type of spectral composition in terms of the *mixing proportions* of three primaries, *not* in terms of the *relative intensities* of the three primary wave-lengths, as present in the light. A colorimeter will measure a pure yellow as so many red and so many green, where a spectrophotometer or Mr. Luckiesh's assumed instrument would find *no* red and *no* green. This illustration will show the caution which must be observed against confusing the three-color measurements,

on which calculations have been made in this paper, with colorimeter measurements as ordinarily carried out. One special limited case has been chosen in which the colorimeter can be used as a spectrophotometer. The calculations show the effect of multiple reflections on monochromatic light. A three-fold repetition of the expression representing this effect with the introduction of the subscripts R, G and B does not make it apply to a colorimeter. The word "colorimeter" had much better have been left out of this part of the paper.

The problem which Mr. Luckiesh has studied can be solved by first working out the effect through the whole spectrum (using many more than three wave-lengths), plotting the results as spectrophotometric curves and then determining the colorimeter values either through the color sensation curves, or by the color mixture curves of the colorimeter used. This process has been published in some detail in the TRANSACTIONS of the Society.

The second part stands alone as a set of measurements made with a different instrument than that "theoretically" discussed and only related to the first part in a very general manner indeed. They are "consistent with the theoretical computations" only in that qualitative way which they must be from the most elementary considerations of the phenomena of light absorption.

A criticism of the second part is that the manner of use of the colorimeter is not described. The essential fact to know about a color mixing instrument is what its primary mixing colors are. In the Ives colorimeter it makes a difference whether the primaries are derived from daylight or from a tungsten lamp, or other artificial source. The description of the instrument as used should, therefore, be included in a revision of the paper.

A further criticism may be made on the manner of plotting the colorimeter results. They are shown in a color triangle whose "white" is the yellow of the tungsten lamp. This means a triangle not heretofore employed, and one in which the relationships are much distorted from those in the usual white light triangle. It is the object of scientific study to reduce the number of elementary quantities to the lowest possible, and to establish exact relationships between them. The employment of this new form of triangle without establishing the relationship of its read-

ings to that of a white light triangle is to be regretted. It is one thing to use different units when the law of relationship is known; it is quite a different thing when the law is not known. The relative positions of points on a straight line may be given without stating the units of measurements, because the relation remains unchanged no matter what the units. In going from one color triangle to another with different vertices or center, the units and so the relative positions of colors suffer distortions not represented by any simple law. It should therefore not be overlooked that measurements plotted in this triangle are not directly comparable with those plotted in the usual forms of color triangle. The measurements are, as they stand much more qualitative than quantitative.

MR. M. LUCKIESH (in reply): I am thankful to Dr. Ives for his interest in the paper.

The theoretical computations made in the first part of the paper are not for a colorimeter at all nor do I make such a statement. The quantities $N_R Q'_R$, etc., on the third page are not meant to represent any colorimeter measurements of mine. They do represent the quantity usually measured in determining the color of paper. I am well aware of what the computations represent, for the method was adopted after serious consideration. A special illuminant was assumed because of the ease in illustrating just what I desired to show which was not only the color changes but also the influence of multiple reflections. I fully appreciate there are other methods for showing these effects, but I chose this one as being the most desirable from my viewpoint.

Dr. Ives' discussion contains nothing which attacks the correctness of my computations. No claims for the results are made knowingly which are not justified by the assumptions.

For the most part of Dr. Ives' discussion which is valuable and scholarly, consists of considerations I had made before adopting the method but which I deemed as unnecessary to embody in the paper.

The latter part of Dr. Ives' discussion takes up the actual measurements with the colorimeter. I am not in a position as yet to make my colorimeter measurements accord with those of Dr. Ives. Therefore it is well to use an altogether different

triangle. It is true the measurements plotted on this triangle do not have quite the same spacial relation to each other as they would have on the triangle used by Ives. But the relative positions of the color values of tungsten and carbon incandescent lamps on my triangle are sufficient to give an idea of the order of magnitude of the changes possible due to colored surroundings. If the other points are shifted more in one triangle than in the other all that is necessary in one case is to describe the green paper as a greener green or the yellow paper as a yellower yellow. It seems like a waste of time to quibble over that point considering the difficulties of accurately describing the papers used.

The methods adopted in this paper are legitimate as long as it is plain that the conclusions are limited by the assumptions. I intended that they should be so and believe they are. There are more ways than one to attack this problem but I chose a method which was clear cut and absolutely free from speculation and am satisfied that it best illustrated what I desired to bring forth.

THEORY OF MERCURY-VAPOR APPARATUS.*

BY PERCY H. THOMAS.

Synopsis: This paper gives a working hypothesis or conception of the actions going on in a mercury-vapor apparatus, from the point of view of the electron theory of electricity. According to the hypothesis of the paper, current consists of electrons passing in the circuit of the apparatus and through the vacuum from the cathode to the anode in the form of material particles. The resistance in the vacuum is due to the obstruction of the molecules of the gas or vapor in the space, and the pressure of the vapor is the ordinary pressure of saturated vapor in the presence of its liquid, as the mercury electrode, and is determined solely by the temperature of the mercury. The paper also explains the fundamental characteristics of the high pressure mercury-vapor lamps in quartz tubes.

The theory of the mode of operation of the well known mercury-vapor apparatus, characterized by a hermetically sealed container exhausted to a high degree of purity and enclosing suitable positive and negative electrodes, is, more than that of most physical apparatus, dependent upon the aid of the electron hypothesis of the nature of electricity. The characteristic observed properties of this apparatus, as distinguished from the theory of its operation, are very simple in the fundamental embodiment and are well known.

As to the voltage consumed in a mercury-vapor device, it may be stated that the drop of potential is practically constant for values of current above a certain minimum, regardless of the strength of the current, provided the vapor pressure of the mercury vapor is maintained constant. Of this constant voltage consumed in the device, there is a certain portion, also constant, consumed at each electrode, while the remaining constant portion is consumed in the passage of current through the vacuum or vapor space. Only this latter portion of the total voltage drop is dependent upon the length and diameter of the vapor path.

The above statement as to voltage drop applies to the operating lamp. Before starting, the conditions .are, however, entirely different. The device operates as though it contained somewhere a rigid obstruction to the flow of current, which obstruction sub-

* A paper read at a meeting of the New England section of the Illuminating Engineering Society, Boston, February 17, 1913.

stantially disappears when once overcome. A study of the behavior of this apparatus, particularly its behavior when utilized as a rectifier, points conclusively to the surface of the electrode impressed with potential in the negative direction, that is, to the cathode, as the location of this peculiar obstruction to the starting. This fact is established partly by the observed condition that the starting obstruction, or "reluctance," as it is called by Dr. Hewitt, can be overcome by various operations *at the surface of the cathode* and can not be overcome by any operations in any other part of the device, and is partly demonstrated by the fact that, with the device connected according to the ordinary method as a rectifier, namely, with two anodes connected to the terminals of the supply and the cathode connected to an intermediate point of the supply, current will flow freely in any direction in the vacuum space and will flow out of any electrode impressed with a positive potential and yet current will not flow between the two anodes, one or the other of which is always impressed with a positive potential while the other has a negative potential. Since now it is known that the anode impressed with the positive potential will not oppose the flow of current from the anode into the vapor and since it is known that current can flow in any direction through the vacuum space, it must follow that the reason the rectifier does not short circuit or "arc" between the anodes, in other words the reason that current does not flow directly between the main anodes, is the existence of some sort of obstruction or reluctance at the *anode impressed with the negative potential,* which is in fact the case.

One other characteristic property of the apparatus I wish to bring out, namely, that the voltage consumed in the vapor path proper depends upon the vapor pressure or density of the mercury vapor inside the container. Since there is liquid mercury in the enclosed space and no gas or vapor except the vapor of mercury, the pressure of the mercury vapor within must always be the pressure corresponding to the vapor tension of mercury at the temperature of the liquid mercury itself. This is seen to be true since, were the vapor pressure less than the appropriate value, the liquid mercury would evaporate until the pressure of saturation be reached and were the pressure in the vapor greater, vapor would be condensed until again the pressure of saturation

corresponding to the temperature of the electrode be obtained. Therefore, the only way to increase or decrease the pressure in a mercury-vapor tube is to increase or decrease the temperature of the liquid mercury.

One more point. When mercury evaporates it absorbs heat; when it condenses it liberates heat, as in the case of any liquid in the pressure of its vapor; consequently, if heat be generated in liquid mercury within the condenser, an equivalent amount of heat will be transferred to the coolest part of the wall of the container by the evaporization of mercury at the electrode and the condensation of mercury on the wall of the container. From this it follows that where two bodies of mercury, as for example two mercury electrodes, exist in the same device, they must necessarily have their surfaces at approximately the same temperature, since otherwise mercury would evaporate from the hot electrode, thus cooling it, and condense on the cold electrode, thus heating it. Many of the features and characteristics of mercury-vapor apparatus can be explained or understood by a knowledge of these principles. For example, the use of a condensing chamber as a means of controlling the temperature of the lamp that is, that of the mercury cathode, the vapor pressure and the voltage consumed in the vapor path, may be clearly understood.

It is now in order to consider the electrical action of the operation of the device, which for the present discussion may be assumed to be a lamp. A flow of electricity, according to the electron hypothesis, to which I personally subscribe, is nothing more than the passage of electrons along a circuit. It is known that these electrons are physical bodies of extremely small mass, requiring between one and two thousand to give the mass of the hydrogen atom, and carry a definite negative electrical charge. These electrons exist in a relatively quiescent state in all matter. Since the charge carried by the electrons is negative and since unelectrified bodies show no resultant electric charge, it must follow that in such unelectrified matter the negative charge on the electron is balanced by some positive charge in the material.

There will be no flow of electricity in an electric circuit, that is, no flow of electrons, until something disturbs the condition of electrical balance of the unelectrified matter. When-

ever, however, the electron is separated from the positive charge which ordinarily neutralizes its external electrical effect and when there exists at the same time an electro-motive-force in the neighborhood of this electron, the electron will endeavor to follow the electro-motive-force and produce a flow of current. But electrons like other material particles or bodies can not move unless they have a free space in which to move. In all metal conductors it appears that there are passages or spaces between the atoms or molecules through which the electrons can pass relatively freely, although they will experience some resistance (the well known ohmic resistance of the metals). Electrons set free in insulating material, however, do not find any passageways open for motion from one place to another, hence the electrons with their charges remain fixed in location. This is illustrated, for example, by the rod of sealing wax and the catskin. When rubbed by the skin the rod becomes electrified, but the electricity remains fixed in position. Under this condition the electrons are stuck, so to speak, in the insulating material.

Although air is ordinarily an insulator it is generally assumed that air and other gases may be made under certain conditions to be good conductors of electricity and while, in a certain sense, that is true, it is, nevertheless, not analytically true. The principal reason that electricity does not flow through ordinary air and gases is that there are no free electrons in the gas to move in response to an electro-motive-force. When free electrons are introduced or produced in a gas, they do pass along through the gas if a suitable electro-motive-force is present. They pass, however, not through the atoms themselves but in the space between them. This action is very much complicated, however, by the fact that part of the progress may be due to the movement of the molecules of the air itself and by the fact that electrons have an attraction for gas molecules and stick to them, sometimes collecting quite a group of molecules called an aggregate. The transfer of electricity in the form of electrons, freed or liberated in air, is illustrated by the progress of a thunder cloud where the electric charges travel considerable distances with the air and probably to some extent through the air itself, slipping between the molecules. If electrons be set free from the atoms of the

gas, as can be done with the aid of X-rays, and an electro-motive-force be applied, as was done by J. J. Thomson in his famous experiments in which he applied electro-motive-forces of opposite signs to parallel plates, there will be an actual flow of current through the air due to the passage of electrons through the air. Such currents are always very small, however, since up to the present time no method has been devised for producing large quantities of free electrons from gases, under any such circumstances.

In the electric arc in air a large number of electrons are liberated from the cathode and force a lane or passageway to the anode, probably by crowding back the molecules of air.

The electron and its neutralysing positive charge, when in a state of equilibrium and constituting a state of non-electrification, have an attraction for each other and can not be separated without the exertion of a considerable force and the expenditure of a certain amount of energy and ionization, as such separation is called, is ordinarily a difficult process. The forces being inter- or infra-automatic are very large in proportion to the physical size of the electrons. Furthermore, it is difficult to employ the powerful forces available in connection with large masses of matter in such a way as to be effective in separating the electrons from an atom. Electro-magnetic waves of very short wave-lengths seem to be effective in producing this result. Ionization may be produced by such waves as are supplied by X-ray apparatus or by ultra-violet light. Another very effective method of producing ionization, that is the separation of electrons from atoms, is the shock caused by the striking of one atom by another atom or by an electron proceeding at a very high velocity.

Electrons are always free and able to move within metallic conductors as long as they do not go outside.

Now the electric circuit containing a vapor electric device having a high vacuum between two electrodes may be considered. If an electro-motive-force be impressed in such a circuit the electrons will flow freely in the metal parts of the circuit from a point of low potential to the point of high potential (they move backward on account of their carry-

ing a negative charge) until they reach some point where their progress is blocked that is where the electrons are not free to move. They are free to move, however, in all that part of the circuit constituted by metal conductors. Following the electrons within these metal conductors one finds them flowing freely toward the cathode of the device until they reach the surface of the cathode exposed in the vacuum. But the electron can not leave the surface of the cathode without overcoming the attraction of this electron for the corresponding positive charge associated with it. It could move freely in the body of the metal since in leaving one positive charge, it could pick up another from an adjacent atom. These electrons then accumulate at the cathode surface producing there a negative charge; similarly electrons are withdrawn from the anode producing there a positive charge, which two charges impress the electro-motive-force of the circuit on the vapor path in the vacuum space. Now were there a supply of free electron in the vacuum space, they would be immediately drawn out of the vacuum space into the anode producing a flow of current as long as the supply lasted. As has already been pointed out there is no material opposition or resistance to the *entering* of a metal conductor by a free electron since no counter attraction for a positive charge must then be overcome. If, however, the electrons which have accumulated at the surface of the cathode could overcome the attraction they have for their positive charges and get into the vacuum space they would leave the cathode and there would immediately be a stream of electrons between the electrodes in the vacuum space giving a flow of current and there would be no limit to the amount of this current unless a limit developed in the supply of electrons. But the supply of electrons is unlimited in the metals.

Now when a mercury-vapor lamp is started into operation, this means merely that a means has been provided for liberating electrons from the surface of the cathode. Then these electrons are free to flow under the influence of the electro-motive-force of the circuit from the cathode through the vapor path to the anode and into the anode through the metallic circuit outside, back through the cathode lead to the cathode again. In this circuit there is developed, of course, a certain amount of resistance in

each part of the circuit; the well known ohmic resistance in the metallic conductors; a certain resistance to the liberation of electrons at the cathode surface, and a certain resistance to the passage of electrons through the vapor space. This latter resistance, namely the resistance to the passage of electrons (or current) through the vapor space results principally from the jostling and blocking of the electrons by the atoms or molecules of the vapor present which get in the path of the electrons. The lower the pressure of the vapor the less this resistance and the less the voltage absorbed in the vapor path; the higher the vapor pressure, the greater the tendency to impede the progress of the electrons and the resistance of the lamp or its voltage drop.

In a lamp, however, it is this jostling of the vapor molecules that produces the light and the more vigorously they are jostled, that is, the greater the volume of the current flow and the greater the number of electrons, the greater the amount of light; and again the greater the number of vapor molecules, that is the greater the vapor pressure, the greater the amount of light.

After starting up a mercury-vapor lamp cold, although there is at first an abnormally large current, there is very little light produced. This is because there is very little vapor present and a relatively small number of vapor molecules are jostled. As the lamp warms up, however, although the current becomes somewhat less, the amount of light given is far greater since the number of molecules of vapor is greatly increased on account of the higher vapor pressure.

The warming up process comes to a stage of equilibrium when the heat radiated or dissipated from the surface of the lamp equals the heat generated in the lamp. If now the heat dissipating capacity (for example by the use of a condensing chamber) of the device is so proportioned that this equilibrium is reached when the mercury temperature is somewhat above the boiling point of water one has a mercury-vapor lamp of the low pressure type; if on the other hand the heat dissipating power of the lamp is reduced so that equilibrium is reached at a considerably higher temperature, there is obtained the high pressure type of mercury-vapor lamp, the type for which a quartz container may be advantageously used.

Returning now to the surface of the negative electrode and the means by which the starting reluctance of the cathode is overcome and electrons are freed from the body of the cathode material, it is necessary to confess that the exact mechanism of this process is not known with certainty. A prominent characteristic feature of the process is, however, the so-called cathode spot or bright spot of light at the point where the electrons leave the cathode surface, which is one of the features distinguishing this light from the so-called Geisler tubes. At this spot something is going on which is liberating electrons from their associated positive charges in the atoms of the liquid mercury. It may be that the heat generated by the current flow concentrated at this point produces a very dense vapor and that the current which is greatly concentrated at this point serves to ionize this concentrated mercury vapor very energetically, this liberating of electrons serving to secure the continued flow of current in the vapor space. In any event there is some result of the flow of current at any one instant which provides for the liberation of electrons to constitute the flow of current during the next instant. Whether this be an extremely local heat effect or the rapid ionizing of vapor generated locally or whether it be the liberation of electrons directly from the liquid mercury by the bombardment of other electrons or positively charged atoms has not been determined. It is interesting to remember, however, that if there is an extremely plentiful ionization of vapor at the cathode spot there will be produced by the current flow first electrons which will be attracted to the anode and second there will be liberated by these electrons the corresponding positively charged atoms, which will be attracted to the cathode by its negative charge. It may be that these latter atoms which must be continuously bombarding the cathode are the means of liberating electrons from the cathode to support the flow of current. However this may be, the fact can hardly be controverted that the essential action which eliminates the initial starting reluctance is closely related to some mechanism operating in the cathode spot and self perpetuating when once started, as long as a flow of current in sufficient volume continues.

It is a well known fact that if an attempt is made to start a flow of electricity through an extremely highly exhausted space

that enormous potentials are required. It was customary originally to attribute this phenomenon to the supposed absence of a conductor in the vacuum space, but our present electron hypothesis has shown that electricity, that is electrons, being physical bodies move with the greatest facility in a vacuum and that the reason that the vacuum device resists the initial flow of current so stubbornly is the fact that no means exist for liberating electrons within the vacuum space from the surface of the cathode which is the only point at which they can be produced, since there is no gas or vapor in the vacuum which can be ionized to produce electrons. The high voltage required for starting in the high vacuum is to be expected since it is only by forces acting directly on the *atoms themselves* that electrons can be produced from solid or liquid materials and a very high starting voltage must be provided since it must be applied at a distance.

When, however, the vacuum in the device just discussed is not perfect and a certain residual gas is present, the high voltage applied to the terminals is sufficient to ionize this gas producing electrons and positively charged atoms. These positively charged atoms, as already described, will be attracted to the cathode surface where they will bombard the material of the cathode, thus liberating further electrons and positive charges which repeat the process until under favorable conditions the permanent condition of current flow as already described is attained. The nature of these phenomena explains why the salient starting characteristics of the cathode in a vacuum are not observed in electrodes in the open air, at any rate to anything like the same extent as in the vacuum. The presence of the air between electrodes provides a source of electrons and positive charges automatically sufficient to liberate electrons from the cathode, whenever a suitable voltage is applied. Furthermore, the presence of the molecules of air in the path of the current when once started so greatly increase the *operating* voltage that the effect of the starting reluctance would be practically overshadowed.

With this exposition of the hypothesis or conception of the nature of the operation of a mercury-vapor device which has satisfied me personally and seems consistent with practically all the fundamental principles now established in electro physics, as far as I know them, there remains very little to be said in

explanation of the theory of operation of the practical mercury-vapor lamp, either the low pressure lamp or the high pressure lamp in the quartz container.

It may be well to call attention, however, to one characteristic of the quartz burner of great practical importance in its operation, though purely incidental in the electrical hypothesis involving its principle of operation. I refer to the fact that the quartz burner operating as intended in the Cooper Hewitt commercial quartz lamp, is approximately a constant current device. That is if the voltage applied in such a lamp is raised the only effect is to increase the voltage on the tube without material change of current through the tube. Of course, the first momentary effect of the increase in voltage is an increase in the current, but this increase in current raises the temperature of the lamp thus increasing the temperature of the mercury electrode and the pressure of the mercury vapor. This, in turn, increases the resistance of the lamp or the voltage consumed therein and the point of equilibrium is found finally at a current only slightly greater than the original current flow. Lowering of the voltage merely produces a lowered voltage on the tube when equilibrium is finally attained with but a slightly decreased current. These same characteristics are found in the low pressure lamp but are there not as marked. The particular significance of this phenomenon lies in the fact that if an attempt is made to adjust the series resistance of a high pressure lamp which is being installed to the proper value by the insertion of an ammeter in the circuit, it will be impracticable to make a satisfactory adjustment, since the difference between the current shown on the ammeter with a very low value of the series resistance and that with a very high value will be very slight indeed. On the other hand, if a voltmeter be placed in shunt to the burner it is possible to adjust the series resistance with great accuracy and certainty, since the voltage on the burner is very sensitive to the proper setting. With the use of a voltmeter it is not necessary to pay any attention to the current, for this will take care of itself.

If it is for any reason desired to increase the current in a high pressure burner (that is the tube) this must be done by increasing the natural dissipation of heat from the burner to give it a lower temperature as by placing it in a cooler place or

by directing a draft on the tube or otherwise. In such a case the net result of the cooling is to lower the temperature of the electrode and the pressure of the mercury vapor. The result of the lowering of the voltage or the pressure is an increase in the current. This increase in the current will then heat up the burner until the vapor pressure and the burner voltage again bears the right relation to the supply voltage. Vice versa, when placed in an abnormally hot atmosphere the burner will take an abnormally small current. Thus, in very cold weather or with a cracked globe the tendency of a quartz burner is to take a large amount of current while its voltage may remain approximately normal.

Another result of this characteristic of the quartz burner is the difficulty of running the constant potential quartz burners in series; for suppose a number of such burners to be placed in a constant current circuit; some of them will naturally run a little hotter than others either from variations in the structure or from different temperature conditions at their points of installation. Those naturally running hotter will be taking a little too much current and those running cooler will be taking too little current, but all are forced to take the same current since they are a constant current circuit. Since now these devices are constant current devices, naturally those taking too much current will heat more and more and the hotter they tend to get (since the added vapor pressure and resistance from the added temperature increase the heat generated in the burner, even if there be no increase of current). It thus soon happens that a few burners take nearly all the potential and perhaps ultimately get so hot as to put out the whole series. The same general difficulty was originally met with in arc lamps, but was overcome by the use of shunt regulating coils coupled with means for adjusting the length of the arc between electrodes. The constant potential type of mercury quartz burner does not provide, however, for such adjustment and this method is inapplicable.

DISCUSSION.

MR. C. F. LORENZ (communicated): It is interesting to see that the electron, which has come to play such a familiar role in the every day thought of physicists, is also commencing to penetrate into the transactions of technical societies.

The author presents a very clear and simple picture of the inner nature of the things going on in a mercury-vapor tube, but in doing so he throws an even greater burden on the electron than is customary. He speaks of the flow of current as being entirely constituted by the motion of electrons. Ordinarily we think of both positive and negative carriers as entering into nearly every kind of electric discharge; an exception is the cathode ray stream in an X-ray tube; another is the discharge of a negatively charged incandescent solid when located in a very high vacuum. The author of the paper recognizes the presence of positively charged particles in the mercury-tube when he speaks of the bombardment of the cathode as the source of ionization at the cathode during the arc-discharge; why should such positive charges not take part in the process of conduction throughout the tube?

Thinking of positive and negative charges leads to an explanation of the "reluctance" which differs from the author's. Before the arc is started there must be ionization to some extent and the application of the difference of potential causes motion of the positive and negative charges which constitutes the minute current then flowing; a resistance must immediately develop at both electrodes owing to the scarcity of ions which immediately exists in the regions adjacent to the electrodes, since the solid electrodes do not furnish carriers to replace those swept out of these regions in the act of conduction. The cathode drop is enormously greater than the anode drop because of the much greater mobility of the negative carriers.

A point discussed in the paper of much general interest apart from its importance in the operation of the quartz mercury "burner" is the behavior of the latter as an approximately constant current device. Carbon incandescent lamps, Nernst glowers, metalized filament lamps, and metal filament lamps all have their own mode of behavior under varying voltage, which makes them useful as resistances for special purposes, at least in experimental work. The very peculiarly behaving quartz mercury lamp is a welcome addition to the list of automatically varying resistors.

Dr. E. Weintraub (communicated): The electronic theory of the operation of the mercury arc given by Mr. Thomas does

not materially differ from the one current at present among those working in the field and would, therefore, call for little comment. I, myself, have on different occasions expressed similar views.

It is true that the electronic picture of the arc is somewhat vague and indefinite, that especially the role of the positive electricity is not clear, but these imperfections can be ascribed and perhaps justly so to the inherent complexity of the arc. From the point of view of the engineer and inventor a more serious objection to the theory is the little help it has offered so far in the technical development of the mercury arc and other arcs. I for one had to work my own way by direct study of the phenomena and by the analogy method of reasoning.

However, the electronic theory is the theory of our age, is a partial expression of the truth, gives a new cross-section through the infinite complexity of the natural phenomena and whatever its ultimate fate may be one can hardly do better at present than to accept it and use it as far as feasible.

It is, however, to be regretted that Mr. Thomas found it necessary to obscure his electronic exposition by still retaining the conception of a "starting reluctance" at the cathode which has no place in the electronic theory of the arc and for that matter in any scientific theory. The author himself later explains that the evacuated space contains no conductive matter, that the latter has to be produced at the cathode and that an expenditure of energy is therefore necessary at or near the cathode. If this justifies the assumption of a starting reluctance then the whole universe is full of "reluctances." Whenever for lack of energy or for lack of another sufficient reason a certain transformation does not happen then there would be an equal reason to postulate a "reluctance."

With respect to series operation of quartz mercury arc lamps the evil of running away on constant current which is described by Mr. Thomas is less pronounced in the case of the new type of quartz lamp that I have developed recently and what is left of it is overcome by special automatic regulating means so that at present the quartz mercury arc lamp is available for both alternating current and direct current series circuits.

STREET LIGHTING WITH ORNAMENTAL LUMINOUS ARC LAMPS.*

BY C. A. B. HALVORSON, JR.

Synopsis:—This paper outlines the general lighting requirements of business and residential streets and parkways. For business streets it is contended (1) that the illumination should be of a different color and character from that employed in store windows in order that the effect of the latter may not be impaired, (2) that the illumination should be comparatively brilliant, though not greater than the intensity of the windows, to attract trade and insure traffic safety. Residential street lighting, in the opinion of the author, requires the use of as few light sources as possible to produce the average low intensity of illumination, and that a non-uniform illumination is more desirable than an extremely uniform one. Parkway and driveway lighting demand primarily an illumination of sufficient intensity from light sources of low intensic brilliancy to insure traffic safety. In all three classes of lighting the decorative possibilities of ornamental lamps and standards is said to deserve particular consideration.

In planning a system of exterior illumination to meet the requirements of the city of to-day, the needs of each section of the city must be carefully considered. The shopping centres demand one type of illumination peculiarly their own; the residential streets, open parks, drives and outlying districts each in their turn require special consideration and quite different treatment, as regards both the illuminating units and the ornamental standards or fixtures employed.

Unfortunately, it is quite impossible by the use of illuminating data alone to show exactly what system of lighting should be employed in each case to accomplish the best results, as frequently certain psychological and physiological requirements play parts of vast importance.

The lighting of business streets requires, in addition to the usual purposes of good general lighting (police protection, ability to read easily and distinguish persons, etc.) an illumination tolerable and pleasing to the eye, yet sufficiently brilliant to produce a marked effect in the improvement of business—obviously a matter of great general interest to the city—by attracting people to the brilliantly lighted thoroughfares and at the same time allow-

* A paper read at a meeting of the New England section of the Illuminating Engineering Society, Boston, February 17, 1913.

ing their attention to be drawn freely to the matter of most importance, which is of course, the attractive window displays and decorations. This object is largely attained by means of the contrast between the color schemes employed in these decorations and the color of the general illumination. It follows, therefore, that general illumination must be furnished that differs in color from the illumination obtained from the small lighting units usually employed in the merchant's local display, and also differing from and not interfering with the color effects obtained by reflection or secondary illumination from the goods displayed. White light falling on the show window from without can only enhance the color values by showing them correctly. Obviously, then the color and quality of the light play a most important part in successful lighting of this kind; accordingly white light of low intrinsic brilliancy must be employed in order to obtain the best results.

The intensity of the illumination, perhaps, should be considered of next importance, for the ratio of general illumination to window illumination should be such that the window illumination far outweighs the general illumination. As good window display lighting requires in the neighborhood of 15 foot-candles, it is highly improbable that any economical scheme of general illumination that could be obtained, would approach this figure. A possible exception is yellow flame arc lighting; but this, on account of the color, would be highly unsuitable, assuming that such illuminants were placed low, as they usually are in this country, and in the direct range of vision; in which case an immense volume of light would be directed toward the show windows.

Other important considerations are: the appearance of the lighted unit; the illumination of the building fronts from both esthetic and economic viewpoints, the latter particularly as regards the benefits accruing the upper-floor tenants; the daytime appearance of the lighting standard, dignified, simple, or ornate, as harmony with its surroundings requires, and yet unobtrusive and free from overhanging arms and glassware that might impede teaming and endanger pedestrians. Above all the lighting unit must aid in beautifying the street rather than produce the effect

of crowding and over-burdening which is so characteristic of many systems of so-called ornamental lighting.

The problem of laying out a "great white way" system as described above is quite different from the problem of lighting the streets of the residential section, for the latter is largely a utilitarian one and bears on the matter of police protection and suitable lighting for pedestrians, motorists, and other users of the thoroughfare.

Residential street lighting is from its very nature of low average intensity. As this class of lighting comprises a relatively large percentage of the city's streets, it is important for obvious reasons that the most efficient unit suitable be used. It is desirable, also, to employ as few light sources as possible for a given average intensity of illumination, since, the apparent affect produced by many small light sources is that of a very much lower intensity of illumination, because the only images produced on the retina of the eye are those of the light sources themselves. Especially is this so in the case of oiled roadways where the amount of light reflected is relatively small.

In residential street lighting, the principle of silhouette lighting[1] must be employed; that is, seeing is accomplished by the discernment of objects in contrast with a lighted background, which usually is the street surface, rather than by light reflected from the objects themselves.

In the opinion of the writer a non-uniform illumination is more desirable for this class of lighting than one extremely uniform, assuming that the minimum intensity in each case is about equal, but the average intensity higher in the case of the arc lamps than in the case of low candle-powered units; and assuming, of course, the same expenditure of energy per linear foot of street and that each light source is properly screened by means of a diffusing globe.

The proper lighting of drives, highways and parkways requires the use of a specially designed *arc* lighting unit which combines white light with maximum efficiency and a low maintenance cost, as well as a low initial cost when compared with the installation of many small units of

[1] Preston S. Millar, "An Unrecognized Aspect of Street Illumination, TRANS., I. E. S., p. 546, Vol. V. (Oct. 1910).

low candle-power. The cost of installation for such lighting is a serious factor, for there is usually comparatively little money available for this class of lighting. The problem of illumination concerns almost wholly the motorist and drivers of other vehicles. One continually reads of serious night accidents, involving the automobile usually with a horse-driven vehicle or a motorcycle, which, statistics show, could have been avoided had adequate illumination been provided. The requirements of such illumination are not greatly different from those of the residential streets, as described above; that is, in the employment of the silhouette principle of lighting. With such lighting the ability of the eye to see objects clearly a sufficient distance ahead to avoid collision, is greater than with any other type of illumination. Obviously, it is necessary that the light sources should be mounted well above and outside the direct line of vision, and that they should be of low intrinsic brilliancy, as too intense a light source destroys the adaptability of the eye to low average intensity work.

For business streets and other thoroughfares where the requirement is the very best kind of high-intensity illumination, the great white way lamps* may be used, as they furnish pearl-white light of low intrinsic brilliancy, produce correct light reflection from the walls of varied-colored buildings, enhance the window display, and above all, attract people to the streets for the improvement of business.

In many cases a satisfactory spacing for units of this type has

* Since the commercial introduction of the ornamental luminous arc lamp at New Haven, in December, 1911, there have been designed three new forms of ornamental luminous arc lighting units, known as the "Great White Way" lamp (two forms) consuming 520 watts at 6.6 amperes, and 320 watts at 4 amperes; the residential lamp, consuming 300 watts at 4 amperes; and the parkway lamp designed for operation at both 4 and 6.6 amperes, 300 and 500 watts respectively. These lamps are shown in Fig. 1.

The great white way lamps are for use on the principal business streets and cities. The intensity of such illumination of necessity must be high and the distribution good. Therefore, the units employed should be placed comparatively close together.

The residential lamp, as its name implies, in addition to its use in "Great White Way" lighting, is also used on fine residential streets and on boulevards bordered by large estates, where as a rule, shade trees overhang the lamp location. In such cases the low mounting of the light source (12 feet—3.66 m.) permits good illumination as it escape screening by the foliage.

The parkway lamp gives a somewhat more extended light distribution than the two units just mentioned and is designed especially for roadways where an extremely low intensity of illumination is adequate for all purposes. It is usually mounted 18 feet (5.486 m.) above the roadway.

been found to be approximately 75 to 100 feet (22.86 to 30.48 m.) on centers on each side of the street, with the standards in a staggered arrangement. It would be impossible to give here any

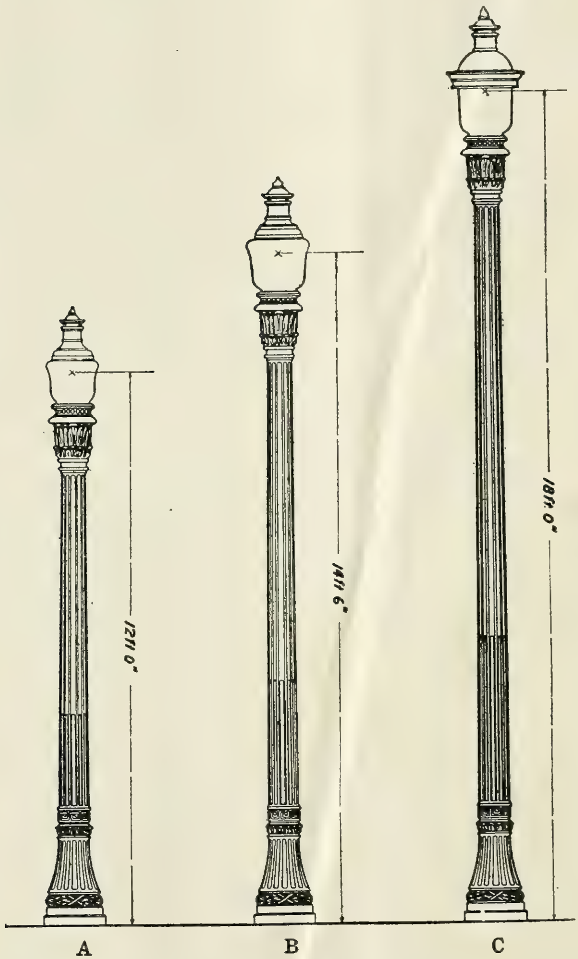


Fig. 1.—Ornamental luminous arc lamps and standards for (A) residental streets, (B) "great white way," and (C) parkway lighting.

definite statement on the exact arrangement to be followed for future installations, as obviously each case must be considered

by itself; the character, height and color of the buildings, as well as the width of the street, all playing important parts.

For residential streets and broad boulevards where the screening effect of foliage must be considered and for all other lighting classified under the heading "second class," the residential lamp (see A, Fig. 1) can be employed to give the best results.. The spacing of this lamp, like that of the lamp just described, varies with the local conditions, but 300 feet (91.44 m.) apart in staggered arrangement gives an exceedingly satisfactory illumination.

An installation of this character will show fewer light sources within the range of vision, beautify the streets to a much greater extent, and produce a more satisfactory illumination for the same cost of installation and maintenance than any other lighting unit available at the present time. The globes used with these lamps act as secondary sources of pure white light of low intrinsic brilliancy; consequently the units themselves are extremely pleasing to the eye by night as well as by day, fulfilling all esthetic requirements.

For highways, open parks and drives and all other purposes where an efficient ornamental unit is desired and where there is but little danger of screening the light source by foliage, the parkway lamp (see C, Fig. 1) may be employed in order to utilize to the highest degree the principle of silhouette lighting.

With these three units it is believed that the complex and exacting requirements of scientific street illumination can be successfully met, both from a utilitarian and from an artistic viewpoint. The introduction of the smaller and consequently lower candle-powered units will be greatly appreciated by those cities which possess at the present time an installation of the pendant type of standard luminous arc lamps, as these new ornamental units are interchangeable with the pendant type units insofar as their operating characteristics are concerned, and contain many vital mechanism parts such as magnets, clutches, etc., which are common to both. This feature is one which will be greatly appreciated by the operating man.

DISCUSSION.

P. S. Millar (communicated): Mr. Halvorson's paper is somewhat radical in that it departs from the traditional view that small illuminants should be employed on side streets and in residence districts.

Two points are particularly worthy of note, although some may question the correctness of the author's view. The first is that comparatively brilliant illumination of a thoroughfare does not detract from window displays if there is considerable contrast between the color of the street light and that employed in the windows. The other is the importance of the appearance which the street lighting fixtures present in the daytime, and the part which they play in the general appearance of a street. Both points well merit greater consideration than has been given them in the past.

The silhouette effect in street lighting, which is emphasized so strongly in this paper, is of greatest importance where the requirements are for the discernment of large objects. Lighting of streets with few large units rather than with many small ones is likely to promote this form of seeing. It must not be forgotten, however, that the requirements for the discernment of small irregularities in street surface are important, particularly to the pedestrian and the driver of a slow moving vehicle. For any given street and lighting appropriation there is probably some superior balance between the requirements for the discernment of large objects by silhouetting and the discernment of street surface irregularities, and this is likely to imply some balance between number and size of light sources.

The illuminating effect is one of a number of considerations which determine the choice of a street lighting system. Insofar as it is the leading consideration, our understanding of street lighting requirements is rather vague. Much remains to be done in the study of street illumination before the principles which determine this balance between number and size of units can be announced. Until then, practise must be guided by conclusions drawn from views of individual experts, one extreme of which appears to be represented in this paper. It is the logical conclusion of this extreme view that in all classes of streets, lamps

which are of relatively large power may be employed to secure best results. There will probably be many who will take issue with the author in regard to this conclusion. It is to be hoped that the study of this question may be undertaken seriously, with a view of answering some of the moot questions which are suggested by this paper.

Mr. W. A. Darrah (communicated): I believe that the writer has given a very clear discussion of his subject, but think that perhaps some points are of sufficient importance to warrant a further discussion. It is true that from the standpoint of the effect produced the illumination of our city streets is a matter which cannot be fully expressed in scientific formulae because of the psychological element involved. There are certain points, however, which are capable of rather exact determination.

Whether the lighting of residential sections is considered or whether the illumination is confined entirely to that of business districts, it is my opinion that the light source should be placed well above the range of vision in all ordinary cases, 25 feet to 35 feet, being a desirable height. In fixing upon the elevation of the light sources, consideration should be given to the illuminated signs along the street as well as to the store windows. It is obviously undersirable to mask the effect of an expensive illuminated sign by an arc lamp placed closely adjacent to it.

I believe the writer's contention that a light source of relatively low intrinsic brillancy is desirable, is correct. In this connection I believe the flame carbon arc is a decided step in advance, particularly when used with diffusing glassware. Owing to the relatively large source of light the intrinsic brilliancy of the flame arc is considerably less than that of the older types of arcs.

A further consideration of the subject of street lighting and one which has not been discussed in the present paper is the subject of station apparatus. In deciding upon any general system of lighting, the subject should be considered broadly and in addition to the specific lamps involved, the generating and accessory apparatus should be considered. The simplicity of equipment and low cost of maintenance of alternating current apparatus is a further fact which tends to emphasize the value of the flame carbon arc lamp as a unit for street lighting.

The flexibility of this system in the way of color and intensity is an additional point which should be given full weight in considering a street lighting system. As an example of this flexibility may be sighted the use of white light for the general illumination of business streets with the use of the same lamps equipped with carbons for producing yellow light at busy street corners, fire alarm boxes and other points which require special identification.

J. R. Cravath (communicated): The position taken by the author that it is desirable to employ as few light sources as possible for a given average intensity of illumination on residential streets: this theory is obviously subject to considerable limitation because if it were carried to its logical conclusion we would have but one source of light for an entire length of street.

The author's opinion that non-uniform illumination is more desirable than illumination which is extremely uniform for this class of lighting is open to considerable question. If carried to its logical conclusion, this would drive us back to the old open arc lamp for street lighting, and we would have to discard the later types of lamps such as the magnetite arc which gives a more uniform distribution of light along the street. Within the past few years considerable intelligent effort has been directed toward producing more uniform illumination along a street on the theory that the extreme contrast between the areas of high and low illumination is detrimental to seeing clearly, as is also the blinding effect of high candle-power lamps spaced at infrequent intervals. There is no doubt whatever that changes in the direction of better uniformity have resulted in a decidedly improved street lighting in many residence streets. But there is some question how far we can go in the direction of greater uniformity to advantage, and the point raised by Mr. Halvorson is a very interesting one which should be the subject of thorough investigation before conclusions are drawn as to how far it will pay to go in securing uniformity of light distribution.

Prof. J. M. Bryant (communicated): The author has apparently made a careful study of the general conditions required for lighting in a medium sized city. Too many cities have made

the mistake of putting all their available money into the "great white way" because they have obliged to appease the business men who are influential citizens paying a considerable part of the city taxes.

Within the last few years another portion of the city, namely the better residential portions, parks and boulevards have received more attention since this same influential citizen has found it a pleasure to be out in the evening in his automobile. As yet the poorer business and manufacturing portions of the city as well as the poorer residential portions have received but little consideration as to lighting. Since it is here that the greatest amount of crime exists our aim should be to light and care for these districts in a much better manner, in order to improve the character of the inhabitants and to aid in police protection. We should be as ready to spend the city's money for this purpose as we are our own for charitable or police work among these inhabitants.

No one form of lighting unit can be employed with equal effectiveness or economy in all parts of a city. The arc lamp due to its high candle-power must be used for lighting in places requiring strong light and also rather wide distribution. However, due to the relatively high coefficient of reflection of buildings, this type of unit may be used in business streets. The light reflection from buildings tends to bring up the low intensity areas and make the illumination uniform if the lamps are not too widely spaced. In park lighting and broad boulevards the arc light may be employed to advantage, provided enclosing globes are used, thus lowering its intrinsic brilliancy.

In lighting the streets in residence quarters the lower candle-power unit obtained only in incandescent lamps such as the series tungsten lamp should be employed. On account of shade trees and other features these lamps must be hung relatively low, easily coming into the general line of vision. It has been found advisable to screen even those lamps by globes to make it easier for the eye to distinuish distant objects. I can not agree with the author in the use of arc lamps widely spaced for this part of the installation.

TRANSACTIONS

OF THE

Illuminating Engineering Society

Published monthly, except during July, August, and September, by the

ILLUMINATING ENGINEERING SOCIETY

GENERAL OFFICES: 29 WEST THIRTY-NINTH STREET, NEW YORK

VOL. VIII MARCH, 1913 NO. 3

Council Notes.

A regular meeting of the council was held in the general offices of the society, 29 West 39th Street, New York, March 14, 1913. Those present were: Preston S. Millar, president; C. O. Bond, Percy W. Cobb, Joseph D. Israel, general secretary; A. E. Kennelly, V. R. Lansingh, Norman Macbeth, L. B. Marks, treasurer; C. J. Russell and W. J. Serrill.

An oral report supplemented by a statement of the society's expenses and membership covering the first two months of 1913 was received from the general secretary.

An estimate of the expenses and income of the society for the fiscal year, January 1 to October 1, 1913, was received from the finance committee. The income was given as $8,870; the expenses $8,800.

The following appropriations were authorized: $245 for a typewriter and dictation outfit; $80 for printing and $20 for a membership campaign by the Chicago section.

Payment of vouchers Nos. 1210 to 1240, inclusive, aggregating $790.18 was approved upon recommendation of the finance committee.

Progress reports were received from the committee on collegiate education, the committee on sustaining membership, the committee on section development and the committee in charge of the organization of the New Lake Erie section.

In the report of the section development committee the desirability of establishing a student grade of membership was raised. The secretary was directed to forward to the committee on collegiate education the information and data on the subject contained in the report.

Monthly reports on the activities of sections were received from the following vice-presidents: J. R. Cravath, Chicago section; J. W. Cowles, New England section; W. J. Serrill, Philadelphia section; Howard S. Evans, Pittsburgh section.

The illumination primer committee reported that it had effected a few minor changes in the primer, also that an order for 100,000 copies was pending.

A progress report was also received from the committee on reciprocal relations with other societies.

In accordance with a recommendation of the latter committee the president was directed to appoint committees to care for the Illuminating Engineering Society's part in the fourth International Congress for School Hygiene in Buffalo, August 25 to 30, 1913, and the convention of the American Gas Institute at Richmond, Va., next fall. The arrangement of the joint meetings which

will be held on the occasion of both the latter-mentioned events is the result of activities of the committee on reciprocal relations with other societies.

It was decided to have available for joint meetings with other societies 1,000 copies of the primer for free distribution. It was understood that these copies would be marked "Compliments of the Illuminating Engineering Society" and have on the inside a notation about the work of the society and the prices of the primer.

The committee appointed to devise plans for the appointment of local representatives in cities not having sections of the society reported that it had considered "the question of proper procedure in the selection of local representatives and had come to the conclusion that this is a matter in which each locality presents a special problem by itself. It was thought, therefore, that as questions of local representatives arise they should be handled by the general officers of the society who should consult with the members in the locality in question and use such other means as may seem best to them to arrive at a proper conclusion." The report was accepted and the committee discharged.

It was resolved that the advertising committee should be instructed to complete negotiations for advertising to the extent outlined in their annual report and that further negotiations for advertising in excess of that reported be not made.

President Millar reported upon progress of plans for the reorganization of the International Photometric Commission. President Vautier of that Commission has appointed a sub-committee consisting of representatives of the several national laboratories, which sub-committee has been asked to formulate plans for reorganization of the Commission in such a way as to make it thoroughly representative of illumination interests. Such plan is to be submitted to the several national gas societies for approval. Dr. E. B. Rosa of the Bureau of Standards is the American representative upon the sub-committee. Proposals of the sub-committee contemplate for this country the issuance of an invitation by the American Gas Institute to other national societies interested in light, illumination and photometry to meet for the formation of a national committee, which committee is to delegate representatives to represent the American committee at the first meeting of the proposed Commission, which is projected for Berlin in September, 1913. All of these plans are tentative and subject to change, and the ultimate arrangement may be materially different from that suggested. The present status of the work of the sub-committee is, however, as indicated.

The following letter was received from Mr. Comfort A. Adams, secretary of the Standards Committee of the American Institute of Electrical Engineers:

"At the last meeting of the Standards Committee, it was voted to present to the Board of Directors of the A. I. E. E. the following by-law for their adoption:

'The Standards Committee of the A. I. E. E. is instructed by the Board of Directors of the A. I. E. E. to take no action on any subject matter outside of the field of electrical and magnetic standardization and within the field of the Standards Committee of another national society, before coming to an agreement with the Standards Committee of that society, provided that the said society instructs

its Standards Committee not to take action in electric or magnetic standardization before coming to an agreement with the Standards Committee of the A. I. E. E.'

"As a thirty days' notice is required before the vote can be taken, the Board of Directors will not be able to act upon this until their April meeting. In order to avoid delay, the Standards Committee urge that similar action be taken by your society."

It was resolved that the committee on nomenclature and standards of the Illuminating Engineering Society be urged to adopt a resolution similar to that contained in Mr. Adam's communication.

President Millar was authorized to appoint a committee on time and place for the 1913 convention.

President Millar announced appointments to the various standing and temporary committees of the society which he had made since the January council meeting. These appointments were approved.

New Members.

The following applicants were elected members of the society at a meeting of the council held March 14, 1913:

ARGABRITE, H. M.
Manager, Elwood Electric Light Company, Elwood, Ind.

BUSH, W. E.
Illuminating Engineer, The British Thomson-Houston Company, Ltd., 77 Upper Thames Street, London, Eng.

HULL, SCHUYLER M.
Circuit Breaker Engineer, Westinghouse Electric & Mfg. Company, East Pittsburgh, Pa.

JOHNSON, C. W.
Salesman, Westinghouse Electric & Mfg. Company, 1205 Dime Savings Bank Bldg., Detroit, Mich.

JONES, GEO. A.
Salesman, Macbeth-Evans Glass Company, Pittsburgh, Pa.

KILMER, W. S.
Lighting Engineer, H. W. Johns-Manville Company, New York, N. Y.

KIRKPATRICK, R. B.
Salesman, The Philadelphia Electric Company, 1000 Chestnut Street, Philadelphia, Pa.

KNAUBER, ALEX. M.
President, Alex. M. Knauber Company, 742 Euclid Avenue, Oak Park, Ill.

LYNCH, JAMES D.
Chief Engineer, Lit Brothers, 6th & Market Sts., Philadelphia, Pa.

MUNROE, ROY G.
Service Supervisor, The Denver Gas & Electric Company, Gas & Electric Bldg., Denver, Col.

PEARSON, JULIUS T.
Lamp Salesman, Westinghouse Lamp Company, 27 Woodward Avenue, Detroit, Mich.

ROSS, JAY H.
Secy.-Treas., American Electrical Equipment Co., Kansas City, Mo.

SMULLEN, R. W.
The Philadelphia Electric Company, 1000 Chestnut Street, Philadelphia, Pa.

YOUNG, A. W.
Manager, New Business, Public Service Electric Company, 418 Federal Street, Camden, N. J.

Sustaining Members.

The following companies were elected sustaining members of the society at a meeting of the council March 14, 1913:

Electrical Testing Laboratories.
Holophane Works of General Electric Company.
The Edison Electric Illuminating Company of Boston.
The New York Edison Company.
The Philadelphia Electric Company.

Section Activities.

CHICAGO SECTION

At a regular meeting of the Chicago section in the auditorium of the Western Society of Engineers, Monadnock Block, March 12, Mr. Meyer J. Sturm presented a paper entitled "Practical Idealism in Illumination with Particular Reference to Hospitals." The paper will appear in a later issue of the TRANSACTIONS. Eighty members and guests were present.

NEW ENGLAND SECTION

The New England section held a joint meeting with the New England section of the National Commercial Gas Association in the auditorium of the Edison Illuminating Company Building, 39 Boylston Street, Boston, March 12. Mr. Preston S. Millar, president of the I. E. S., presented a paper on "Some Phases of the Illumination of Interiors"; the paper was supplemented by a demonstration of lighting effects in miniature rooms. The paper and discussion appears in this issue of the TRANSACTIONS.

NEW YORK SECTION

The New York section held a meeting in the United Engineering Societies Building, 29 West 39th Street, New York, March 13, 1913. Three other societies—New York Association for the Blind, Committee on Prevention of Blindness; American Society of Mechanical Engineers, American Museum of Safety—participated in the meeting. Three papers were presented: "Illumination and Eyestrain" by Dr. Ellice M. Alger; "Mechanical Safety" by Dr. W. H. Tolman, and "Industrial Lighting" by Ward Harrison. The first one of these papers appears in this issue of the TRANSACTIONS.

PHILADELPHIA SECTION

The March meeting of the Philadelphia section was held on the 28th of the month at the Pennsylvania Academy of the Fine Arts. Fifty ladies and gentlemen were present at the dinner at the Hotel Walton preceding the meeting. Through the courtesy of the directors of the Academy, the art gallery was open for inspection before the meeting, and this proved a very enjoyable feature. At the meeting Mr. M. Luckiesh of the National Electric Lamp Association presented a lecture and demonstration on the subject of "Light and Art." By means of demonstrations, Mr. Luckiesh showed the effect of direction, color and quantitative distribution of lights on objects of architecture, sculpture and paintings. About 140 members and guests were present.

PITTSBURGH SECTION

A meeting of the Pittsburgh section was held in the auditorium of the Engineers' Society of Western Pennsylvania, Oliver Building, March 14, 1913. Mr. M. Luckiesh of the National Electric Lamp Association, Cleveland, O., presented a paper entitled "Light and Art" which was supplemented by a series of demonstrations showing the effect and influence of quality and direction of light on various art objects. Thirty members were present.

TRANSACTIONS

OF THE

Illuminating Engineering Society

MARCH, 1913

PART II

Papers, Discussions and Reports

[**MARCH, 1913**]

CONTENTS -- PART II

SOME PHASES OF THE ILLUMINATION OF INTERIORS.*

BY PRESTON S. MILLAR.

Synopsis: This paper is an exposition of some of the fundamentals of interior lighting. It treats of the questions of glare, diffusion, direction of light, contrast, influence of colored surroundings on illumination, etc., and describes and illustrates some of the ordinary methods of lighting now in use. The introduction presents a brief discussion of the work and functions of the Illuminating Engineering Society and the illuminating engineer.

I.—THE ILLUMINATING ENGINEERING SOCIETY AND ITS RELATION TO PUBLIC LIGHTING COMPANIES.

The business of the lighting company is to sell illuminating, power and heating service. Its aims and achievements are broader than the mere selling of electrical or gas energy. In the conduct of its business, the well organized large lighting company must have on its staff, power experts, heat and ventilation experts, and illumination experts. The illumination expert should be well qualified to deal with lighting problems, and to the extent that his services are applied on behalf of the company and its customers, the lighting company may be said to be engaged in illuminating engineering work. Such activity, however, forms but an insignificant part of the company enterprise. While its importance is more generally recognized than formerly, such illuminating engineering of necessity is restricted very largely to the application of existing knowledge, rather than to the development of new knowledge in the field of illumination. The lighting company applies developments, and it is only natural that the *art* of illumination (art in the sense of application of knowledge) should be emphasized in lighting company illuminating engineering, and that the development of the

* A paper and demonstration given before the following sections of the Illuminating Engineering Society; New York, November 18, 1912, Philadelphia, February 21, 1913, New England, March 12, 1913.

science of illumination should receive but little impetus therefrom.

Thus associations of lighting companies are interested in the practise of illuminating engineering. And the discussion of improvements in lighting practice is a feature of increasing interest in the meetings of such associations. There are, however, other aspects of illumination not properly included in these proceedings which may not be neglected if the science and art are to be developed properly.

The problem of illuminating engineering may be summed up in a practical way as follows: Illumination must be provided with a view to rendering visible the things which it is desired to have seen. The illuminating engineer, in studying each problem, must ascertain what it is desired to have seen, and for this purpose, must inform himself concerning the requirements and the viewpoints of those who are furnishing the lighting, and those who are expected to see by its aid. In a machine shop, the illuminating engineer must put himself in the place of the mechanic, and must so design the installation that the mechanic can see the surfaces upon which he works and can see to apply tools properly. In the building in which the architect has sought for certain effects, the illuminating engineer must provide light with which to display, in a proper way, those surfaces and ornamentations which the architect desires to have seen. Briefly, the illumination must be designed for the particular purpose for which it is to be used.

The illuminating engineer must not only render visible the things which are to be seen; he must also establish and maintain hygienic conditions for the eyes and body. It must be practicable to see without injury to the eyes, and without discomfort. It may be that in the proper discharge of this part of his functions, the illuminating engineer may be called upon to go beyond his strict province, and to influence conditions other than those of illumination. For example, he may have to urge the use of suitable paper in schoolbooks.

The illuminating engineer must not only render visible the things which are to be seen, and make vision possible under hygienic conditions; he must also consult esthetic requirements, and conform to correct principles of architecture and decoration, thereby satisfying discriminating taste. He must choose

fixtures and lighting equipment which will be in harmony with the character of the installation and the decorations. He must so distribute, diffuse, and modify the color of the light, as to produce pleasing effects.

These three requirements having been met—a tasteful and satisfying installation having been provided, with which it is possible to see with comfort the things which it is desired to have seen—the illumination may be said to be effective, and the work of the illuminating engineer may be said to have attained one of its primary objects. There remains the important and fundamental consideration that these things must be accomplished with reasonable economy. If large energy consumption must be incurred in order to make the installation effective, the illuminating engineer does not hesitate, for the installation is efficient nevertheless. It cannot be efficient unless it achieves the purpose for which it is designed, and large energy consumption or high maintenance cost does not necessarily imply inefficiency. But it is found usually that there is ample opportunity for the expertness of the illuminating engineer to manifest itself in so designing the installation that it shall be effective in accomplishing the purpose for which it is intended, while reducing the cost very materially below that which would be required in order to secure the same lighting effects by inexpert methods.

Here, then, is the illumination art in a nutshell: *to render visible the things which it is desired to have seen; to establish hygienic conditions for vision; to conform to esthetic requirements; and to accomplish these things with reasonable economy.*

It is conceivable that in designing a building those responsible might desire to provide an illuminating equipment which should be as nearly as possible perfect. Having investigated the problem, it might be determined to retain a group of specialists in the various professions which are concerned with the problem. It is conceivable, then, that there would be retained an engineer who is conversant with the properties of illuminants; a contractor who would install the equipment; a fixture designer competent to design or select suitable lighting fixtures; a glass expert competent to produce such quality of glassware as it might be desired to employ in the installation; a physicist qualified to apply optical laws in the design of reflecting and diffusing sur-

faces; an accomplished decorator; a psychologist and an ophthalmologist, who would pass upon the conditions from the viewpoint of vision conservation. These specialists, in co-operation with the architect of the building, would meet to decide upon plans for providing illumination. The viewpoints of each would be important to an extent that would make neglect seriously prejudicial to the success of the lighting installation. Each specialist might be expected to know, or to think that he knows, what kind of illumination is necessary in order to fulfill the requirements from his viewpoint, but he would not know how to obtain such illumination. Furthermore, each specialist would be more or less ignorant of the illumination requirements, judged from the standpoints of the other members of the committee. Whether or not such a committee of experts would be able to agree upon a particular plan for illuminating the building, can be left to the imagination.

The well-qualified illuminating engineer must be informed in regard to the underlying principles of each science and art which would be represented by a specialist on our hypothetical committee. It is too much to expect that he should be an expert in each of these lines:

> "A man so various that he seems to be
> Not one, but all mankind's epitome"

He must, however, have sufficient knowledge of the fundamentals and sympathy with the aims of each of the sciences and arts involved, to bring his work into harmony with them, and it may be noted that he should be better qualified than would the committee, to produce a well-balanced design, because his knowledge of the other phases should enable him to give each its proper weight in final consideration of the subject.

To state the function of the illuminating engineer, is to indicate the work of the Illuminating Engineering Society. It seeks to be the forum where specialists, engaged in each of the sciences and arts which enter into illuminating work, can meet for study and discussion of the problem, exchanging views, learning from one another, and endeavoring to establish correct principles upon which illuminating engineering must be based. Once established, through the meetings and TRANSACTIONS of the Society these

principles are quickly disseminated among the membership, and are applied in the practical work of illuminating engineers. When proven beyond peradventure, effort is made to make them known to the public, as in the case of the Illumination Primer, recently published by the Illuminating Engineering Society.

This brief discussion should serve to indicate the character of the Illuminating Engineering Society. There is a real need for an organization which shall make a specialty of illumination, developing the science and the art so that it may be applied by lighting companies and others. I believe that an impartial study of illumination developments of the past six years will lead to the conclusion that the Illuminating Engineering Society has justified itself by its achievements and by its present status.

II.—DEMONSTRATION OF LIGHTING EFFECTS.

It is a peculiarity of illuminating engineering that the demands are for the highest technical knowledge and skill applied in the common walks of life; that success or failure affects closely the people in their ordinary occupations. The most technical discussion of subjects pertaining to illumination is likely to have a practical application, of interest to the man in the street. It is the purpose of this presentation[1] to indicate in a non-technical manner some of the features of the illumination of interiors which have been studied, and upon which we have some information as a basis for practise.

If a room be illuminated by a bare lamp (Fig. 1, right), the results are unsatisfactory for a number of reasons. In the first place, the walls receive the major amount of the light produced and the portions of the room in which the light is more likely to

[1] For the lecture upon which these notes are based miniature rooms were constructed. These were 4 by 4 feet and 3½ feet high. Wall decorations, as well as lighting equipments, could be altered readily. With one or two exceptions lamps were so operated as to produce 64 lumens in each room. This permitted of comparison of various lighting systems on an equitable basis. With this demonstration equipment a wide variety of lighting effects could be produced and approximately forty were projected. Time limitation, however, restricted those actually presented to twelve which are here illustrated by photographs available through the courtesy of The New York Edison Company.

The temptations to deal with various types of interiors and to undertake studies of color were resisted. Only one type of interior, and that in its simplest form, was considered, time lacking for a more extended discussion.

The suite of miniature rooms was constructed under the supervision of Mr. W. F. Little and was operated under his direction by Messrs. H. Bardwell, M. D. Beuick and W Ihlefeld, all of the Electrical Testing Laboratories.

be utilized, are inadequately illuminated. The light source is unattractive, and, when within the field of vision, is annoying, if not actually injurious to the eyesight. This latter effect, included under the name of glare, is very noticeable in the illustration, where the lamp is at the center of the field of vision, and the effect is exaggerated beyond that which would be experienced by occupants of the room.

If the lamp be shielded from view (Fig. 1, left), conditions are much improved. Much of the discomfort and annoyance disappears. While the distribution of light on surfaces seen within the room is not changed materially, yet everything can be seen more distinctly. Observe, for example, the vertical stripes upon the wall-paper. Beginning near the floor, trace a vertical stripe which is at some height, almost, if not quite in line with the lamp in room No. 1 (to the right). It will be noticed that as the gaze approaches the vicinity of the lamp, it is difficult to see the stripe, and that when level with the lamp, the stripe disappears entirely. In room No. 3 (to the left) in which the lamp is shielded from the eye, the corresponding stripe may be distinguished when looking just past the lamp and screen.

One of the important functions of a reflector or other lighting auxiliary is to thus shield the lamp from view, by interposing between it and the eye, either an opaque or a translucent medium. This is accomplished in room No. 2 (Fig. 1, middle).

But a reflector should fulfill other, equally useful, purposes. In shielding the lamp from view, it may also be made to direct a considerable proportion of the light where it can be utilized to best advantage. Much study has been given to this aspect of the problem, and the performance of any standard type of reflector may be ascertained by reference to photometric tests of light distributed downward may be judged from the floor brightness.
day prepared to supply with their wares. Perhaps in no branch of illumination have such great strides been made in the past ten years as in the design of reflectors in particular, and lighting auxiliaries in general.

It has been noted that the bare lamp distributes but a small proportion of the light downward. In room No. 2 (Fig. 2) a reflector is employed which re-directs downward a goodly propor-

tion of the light, illuminating the card below it much more brightly than would a bare lamp. In room No. 3, this re-direction of light is effected in such a way as to concentrate a large proportion directly below the lamp, thereby illuminating the card to a brightness which is about twice that of the card in room No. 2, which was considerably brighter than the card in the room where no reflector was used.

In room No. 1, as now equipped, a reflector is employed which has been designed without regard to optical laws, and which, though looking like a prismatic reflector, has in fact almost none of the qualities which characterize such glassware. It accomplishes little in the way of re-direction of light, while affording but an ineffectual protection for the eyes against brightness of the filament. It absorbs a certain amount of light without rendering any adequate return in improvement of conditions.

In the three rooms there is illustrated the range of practicable accomplishment in the employment of reflectors, if we omit opaque reflectors, which would not be suitable for employment under such conditions. In room No. 1, general distribution of the light throughout the room; in room No. 2, effective re-direction of much of the light downward, largely increasing the intensity on the table plane, though illuminating the walls and ceiling brightly enough to avoid the appearance of dimness. In room No. 3, the concentration within a small area beneath the lamp is very marked, this being effected by taking from the walls and from the table plane near the walls, a portion of the light which falls upon them in room No. 2, and concentrating it upon, or near the table. The relative intensities of light distributed downward may be judged from the floor brightness.

The correct design of a reflector to accomplish a given purpose, involves the application of well-known optical laws. With prismatic glass and mirror types of reflectors, a wide variety of distribution may be obtained. With opal or phosphate glasses, such as that in room No. 2, the possibilities of securing high concentration are rather more limited, though with this one exception these too may be designed to produce practically any distribution likely to be required.

In achieving the particular distribution which characterizes a given reflector, it is important that the light source be correctly

located with reference to the reflector. The use of an incorrect shade holder, or of an improper lamp distorts the distribution and usually detracts from the appearance and usefulness of the lighting unit.

In reflectors, as well as in globes and other forms of glass lighting auxiliaries, the degree of optical density is important, affecting both the performance and the appearance of the glass. This is an important feature to be considered in selecting glassware. In the now rather common forms of display street lighting, which utilize clusters of tungsten lamps in globes, very displeasing effects are sometimes encountered, due, first, to the non-uniformity of the globes, and second, to the insufficient density which makes the location of the lamp apparent, instead of rendering the whole surface of the globe equally bright, making it appear a ball of light. Much of the lighting glassware in use in residences a few years ago, and it is to be feared even to-day, consists of etched or frosted crystal glass which serves chiefly to give the fixture a somewhat finished appearance. It neither directs sufficient light usefully to make it efficient, nor conceals the light source sufficiently to make it attractive or of value in protecting the eyes.

In Fig. 3 there is a globe of crystal glass, roughed inside, a light opal globe, and a denser opal globe. The last presents a better appearance without involving serious sacrifices otherwise. The light absorptions of these balls are respectively:

Frosted ball	6%
Light opal ball	13%
Dense opal ball	22%

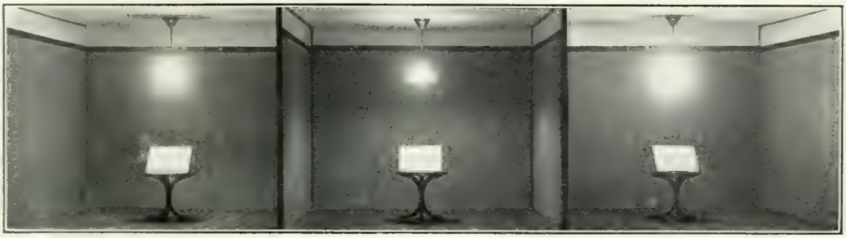
When employed in the miniature rooms shown in Fig. 2 the relative light intensities throughout the table plane averaged:

Frosted ball	100%
Light opal ball	106%
Dense opal ball	95%

In passing I wish to refer to the great diversity of lighting fixtures and glassware which are now available in standard types, awaiting selection. Practically all ordinary requirements in interior illumination may be filled by lighting auxiliaries selected from those now upon the market. In regard to efficiency, most of the reflectors and globes which pretend to be

Room 3. Room 2. Room 1.

Fig. 1.—Showing importance of shading lamp.



Room 3. Room 2. Room 1.

Fig. 2.—Showing variety of light distributions which may be obtained by use of ordinary reflectors.

Light. Medium. Dense.

Fig. 3.—Showing improved appearance when glassware is dense enough to conceal lamp.

Room 3. Room 2. Room 1.

Fig. 4.—Showing appearance with various wall decorations.

Room 3. Room 2. Room 1.

Fig. 5.—Showing appearance with various wall decorations.

Room 3. Room 2. Room 1.

Fig. 10.—Indirect lighting.

efficient accomplish their purpose admirably. In fact so carefully has this element of the question been studied, that an inefficient reflector cannot to-day be successful unless it has some compensating advantage, which renders it superior for some purposes in spite of its inefficiency. I recently went through the interesting experience of making a comparison of the standard types of reflectors which were upon the market ten years ago, and comparing them with types now available. In regard to efficiency, the improvement has been very marked. Absorptions of 10 to 20 per cent. now rule, where ten years ago absorptions of 25 to 40 per cent. were typical for reflectors of substantially similar light distribution characteristics. Improvement in the quality of reflecting surfaces has gone hand in hand with improvement in the design of the curvature of such surfaces. As in efficiency, so it is in appearance. Most of the reflectors of ten years ago were opaque, and few were pleasing to the eye. To-day even in the reflectors where efficiency in light re-direction is the chief aim, pleasing appearance is the accepted order.

In the class of lighting auxiliaries in which decorative effect is the chief object, a wide variety is available, and much of it it pleasing and tasteful. Unfortunately, however, such auxiliaries are characterized by inefficiency to an extent which appears rather unnecessary. It is probable that in the developments of the next few years, we shall note a strong tendency to improve the efficiency of some types of decorative reflectors, without interfering with their decorative qualities.

The influence of room decoration upon the amount of light required to illuminate a room properly is very marked; or, stated otherwise, with a given amount of light produced in a room, the effectiveness of the illumination is largely influenced by the character of the decorations. Considering the simple case of a bare lamp, employed to illuminate rooms having light, medium and dark walls respectively, we may note a number of interesting effects (Fig. 4). In the first place, the illuminated card on the table in room No. 3 appears brighter than the cards in the other rooms. It must be apparent that the card cannot be brighter because it receives light from the lamp and the ceiling only, while the card in room No. 1, for example, receives light from the corresponding light sources and ceiling which is enhanced con-

siderably by light reflected from the walls. The card in room No. 1 is actually 30 per cent. brighter than the card in room No. 3. That it does not so appear is an example of the effect of contrast, which in illumination is a very important fundamental. A corresponding comparison may be made by observing the upper part of the wall in each room, where again the white paper appears brighter in room No. 3 than in the other rooms. Though actually not so bright as the white surfaces in rooms Nos. 1 and 2, these surfaces appear brighter in room No. 3 in comparison with the dark wall-paper to which the eye naturally adapts itself more or less.

In room No. 1, portions of the furniture which are but slightly illuminated, as legs of the table, stand out distinctly, being silhouetted against the light rear wall. In room No. 3, so small is the contrast between the rear wall and the dimly lighted portions of the furniture, that it is difficult to discern the latter.

The glare due to the exposed light source is more serious in room No. 3, due to the larger contrast between the light source and the walls. Shadows of the furniture against the walls are very prominent by contrast in room No. 1, in spite of the fact that the shaded areas are more brightly illuminated by light which is generally diffused within the room.

In considering this photograph, it should be remembered that no light-directing auxiliary has been employed, and that therefore a larger proportion of the light falls upon the walls than good practise would dictate, if we except the darker room. In most installations it is desirable primarily to secure the proper illumination of the lower part of the room, where the light is utilized, the other requirements being that the ceiling and walls shall be illuminated sufficiently to make the effect pleasing. When reflectors are used, the lighting effect of ceiling and wall decorations is reduced greatly, if the reflectors are concentrating in character, and reduced slightly, if they distribute the light rather broadly, about the lower part of the room.

The brightness of walls is an important element, affecting ocular comfort probably more seriously than the illumination of the table plane. Generalizing, it is probably the best rule to avoid extremes of wall decoration, whether they be light or dark. If

the walls are of high reflecting power, it is important to so direct most of the lighting that the amount permitted to fall upon the walls will not render them so excessively bright as to be trying to the eyes. The illuminating engineer cannot control wall decorations, but he can control the light produced within the room, and can so direct it as to secure the best effects.

In the next photograph a reflector which directs the light downward rather largely is shown.

This detracts from the brightness of the upper portions of the walls, the change of course being most apparent in room No. 1, where, due to the relatively high reflecting power of the wall-paper the wall was brightest in the last photograph. The lower portions of the walls are somewhat brighter than when bare lamps were employed. Due to the better lighting of the floor, the lower portions of the table and chairs, which with the bare lamps could hardly be seen, are now slightly illuminated. With this installation the effect of the ceiling and walls is lessened, because a smaller amount of light is permitted to fall upon them reducing their illuminating power. That is to say, when a suitable reflector is employed, the table plane illumination intensity is more nearly independent of reflection from ceiling and walls, and instead of relying upon the latter for assistance in producing useful illumination, the problem is simplified to one of rendering the walls bright enough to produce a cheerful appearance.

It has been shown in the above that the ceiling and wall decorations, when light in tone, may be of material assistance in increasing the illumination intensity on the table plane. It may be argued as the corollary of this, that when the walls are dark and incapable of augmenting the table plane illumination materially, the use of reflectors for that purpose is all the more important.

I have discussed the effect of glare due to the presence of a bright light source within the field of vision. This effect would be almost, if not quite as disturbing, if instead of having a lamp within view, an image of the lamp were to be seen in a mirror. In that event, the effect would be due, not to the presence of the light source, but to specular reflection of the light from the mirrored surface. It is perhaps unfortunate that most artificial surfaces which we are likely to view are sufficiently glossy or

polished to partake in some measure of the qualities of a mirror; that is, to reflect light specularly. Some surfaces which are very mat and free from gloss, diffuse the light so generally that the specular element of the reflection is immaterial for most purposes. But in most paper employed in books and magazines, there is a considerable element of specular reflection, and this characteristic is responsible for much of the difficulty which demands adroit handling by the illuminating engineer in utilitarian lighting.

Referring to the demonstration cards (Fig. 6), it will be noted that the paper and letter on the right half of each have glossy surfaces, while those on the left have diffusing surfaces being almost totally free from specular reflection. On the right half, one may see, when in line with the direction of the reflection, a distorted image, or a number of distorted images, of the light source, much as though he were viewing the source through a very imperfect mirror. On the left it is noted only that the surface is illuminated and no trace of an image of the light source may be seen. From all positions the letter on the left half of the card may be seen. From a particular direction (right photograph), that upon the right half of the card can be seen only with great difficulty, if at all, because it is viewed from the direction in which the glare is manifested.

No small part of the dissatisfaction with illumination installations is due to this effect of glare from observed surfaces. The statement may be ventured also that no small part of trouble with eyes is traceable to the same source. There are three remedies: one is, to eliminate glossy surfaces wherever possible; particularly is this important in schoolbooks, and it is very gratifying to know that serious efforts are being put forth with a view to regulating this matter. The second remedy is to reduce the brightness of light sources as much as practicable by passing the light through a diffusing medium of large area, or by reflecting it from a diffusing surface of large area, in order that when specular reflection from an observed surface is encountered, the brightness of the light reflected may be so low as to minimize the difficulty. The third remedy is to so locate light sources, or to so locate the illuminated surfaces and adjust the position in working or reading, that the direction in which light is reflected

specularly shall not be toward the eyes. All three of these possible remedies should be kept in mind and applied wherever practicable, and any one, or a combination of a part of each of the three can be made effectual in reducing the trouble to a point where it is not serious. The growing appreciation of the importance of this element of illuminating engineering work has been the distinguishing feature of the past two years in the illumination field.

The oil lamp has in recent past years been the standard of comparison for artificial illumination. Even to-day it is traditional among oculists that there is no artificial illuminant which yields a light so free from detriment to the eyesight as does the oil lamp. It is therefore of interest to note some of the conditions under which the oil lamp has been used. Being essentially a small illuminant, and both self-contained and portable, it was natural that it should be placed close to the object viewed. This entailed locating it more or less on a level with the eyes, and so near to the observer that shielding the former became a matter of natural course. In that fact is to be found the reason for the development of the oil lamp shade. Given a small illuminant, shaded for the protection of the eyes, there was no condition under which visual difficulties could be experienced unless it were attempted to read with the book in the illuminated zone near the lamp base, with the reader facing the lamp (Room 1). Under such conditions, glare due to specular reflection from the paper might be detrimental to vision, in which case it would be so immediately apparent that instinctively the reader would shift his position or the lamp slightly, in order to avoid it. With light from this single light source incident upon the page from a direction which would not result in serious glare from the paper, and with the flame shielded from the observer's eyes, the conditions for reading or other work were comparatively good. At the same time, the old oil lamp was well adapted to the illumination of a book by light from over the reader's shoulder (Room 3), one of the best positions for reading. It was in the comparative freedom from misuse of the oil lamp, and the conditions which its employment made natural, that the relative freedom from harmful effect was probably found, if such freedom did exist under those conditions, which is a point that has not been estab-

lished. Of course, no matter how favorable conditions for vision may be, it is difficult to prevent a certain amount of carelessness or perversity in the use of the light (Room 2). Whether it is carelessness which induces Mrs. Lux to read with her page dimly illuminated by light from the ceiling and wall, while facing the light, is open to question. Perhaps she may feel that her appearance is more attractive with the light full upon her face.

Wall brackets may be employed with good effect if equipped discreetly. For utilitarian purposes they are of value chiefly in providing local illumination. It is very difficult to light a room solely from wall brackets (Fig. 8). The light cannot be distributed satisfactorily in the room without placing light sources immediately within the range of vision. Wall brackets find best application when employed in rooms in which the main illumination is provided otherwise and the brackets are equipped with decorative shades, the installation serving purposes of ornament rather than utility.

Daylight, being that under which the human eye has been evolved, may be expected to possess the qualities for which the eye is best adapted. Neglecting other differences between the natural conditions for which the eye is adapted and the artificial conditions with which we have surrounded it, (such as the change from distant to near vision and the change from use of the eye during daylight hours only, to use of the eye for almost as long a period during the hours of the night,) there still remain certain differences between artificial light and daylight, the study of which forms a most interesting field for the illuminating engineer. Daylight out-of-doors is the standard against which we must compare both artificial light and daylight indoors, for the daylight which is available in our interiors differs materially from that out-of-doors in respect to quality, intensity and direction. The intensities may be from 0.01 to 0.001 of those which prevail out-of-doors in bright sunlight. The quality may differ not only in respects which are not perceptible to the eye, but often differs in color due to the influence of the absorption of colored walls, etc., which materially alter the color of the natural light. The direction is usually quite different. In regard to the desirability of such direction of light as that which is prevalent in interiors

illuminated by daylight, there is considerable discussion at the present time, pro and con. My own view is that usually the direction is undesirable. Coming through a window or windows on one side, or at the most, two sides of a room, usually at an angle somewhere between the horizontal and 45 deg. above the horizontal, the light is very unequally distributed. The floor and opposite wall receive the greater part of it, while the wall on the side of the room in which the windows are cut, is illuminated only by such light as may be reflected from the floor and the opposite wall. Persons sitting in the room are likely to have the window and the bright sky within the field of vision, or else they are likely to sit in such a position that their faces are not well lighted. The light is incident upon horizontal surfaces at a very sharp angle, and there is only one good position for writing, or two good positions for reading, if glare from the window or the paper is to be avoided, and as well shadow from the body or hand. Practically the only way of bettering these conditions which has been developed so far, is to utilize a window shade to protect the eye against direct light from the sky, and this is done of course at the expense of the illumination of the room. The usual direction of the light is in my opinion objectionable both from the standpoint of utility and good appearance of the room. The proper utilization of daylight for interior illumination is a subject of which the study has not yet been undertaken seriously.

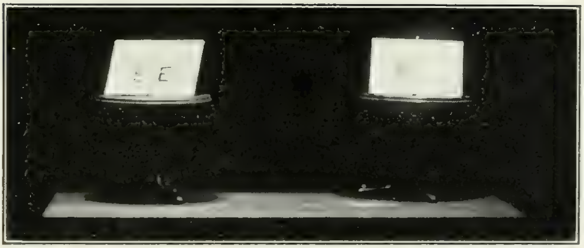
There is one quality, however, in daylight, whether out-of-doors or indoors, which has until recently been lacking in our artificial lighting—and that is, ample diffusion. Interiors are illuminated as a rule from a portion of the sky, the light source being as large as the unobstructed portion of the window. Out-of-doors, even in brilliant sunlight, the skylight is a considerable factor in the total illumination. Of recent years more attention has been given to this quality of diffusion, which previously had been lacking in our artificial lighting. Early consideration of lighting principles brought realization of the harm which exposed light sources work, and led to attempts to conceal the light source. There was evolved, among other systems, that of cove lighting. In the process of concealing the lamps and permitting the light to fall upon a white surface, from which a part of it was reflected into the room, the light was thoroughly diffused. This

system of lighting is more notable in regard to the success with which it concealed the light sources and diffused the light, than in other respects. Historically, it is notable for the evidence which it affords of growing appreciation of some of the principles of good lighting which are now considered to be thoroughly established. The trouble with cove lighting as usually applied, is that control of the direction of the light is lost, and that the flux which is permitted to escape from the cove is diffused promiscuously throughout the room, producing a flat and characterless effect. Only a small portion of the flux is directed where it is most wanted, while perhaps an equal portion is permitted to fall upon surfaces where it is not desired in such quantities. The system has not been largely applied, it being found possible to realize its advantages by other methods which are free from some of its disadvantages.

More recently another system of indirect lighting has been developed, in which central fixtures are employed to conceal the lamp from view and direct much of its light to the ceiling, from which surface it is diffused downward. More engineering study has been devoted to this system of lighting, and in consequence its possibilities have been more largely realized, than were the possibilities of cove lighting. This system of indirect lighting has been widely exploited, and has given considerable satisfaction in a wide variety of installations.

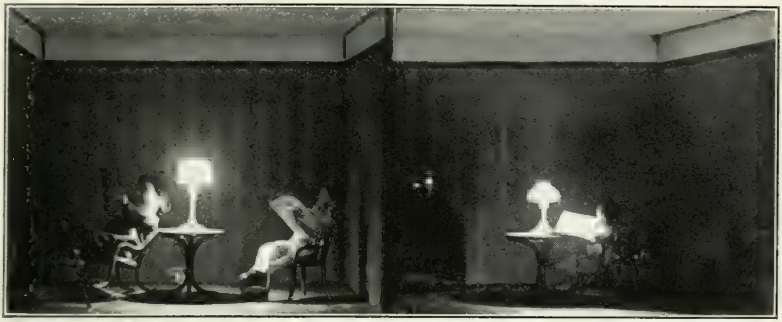
Direct lighting, in which the great bulk of the light utilized comes directly from the light source, had been abused with detrimental results. Particularly was it lacking in diffusion. Indirect lighting is the other extreme, possessing in a high degree the element of diffusion which is so often lacking in direct lighting systems. The rapid growth of indirect lighting is the manifestation of a protest against abuse of direct lighting. Its effect has been to introduce into direct lighting practise a considerable general improvement, which has corrected, or decreased some of the evils of direct lighting. And too much credit cannot be given to the exploiters of indirect lighting devices for the beneficial influence which they have exerted upon our lighting practice in general.

In the lighting fixtures here shown (Fig. 10), the lamp in the metal bowl is backed by an efficient mirrored reflector, which



Viewed from direction in which glare is not apparent. Viewed from direction in which glare is apparent.

Fig. 6.—Showing glare due to specular reflection from glossy surface.



Good reading posture. Very undesirable reading posture. Undesirable reading posture.

Fig. 7.—Showing manner in which a table lamp may be used.

Fig. 8.—Illumination from wall brackets alone.

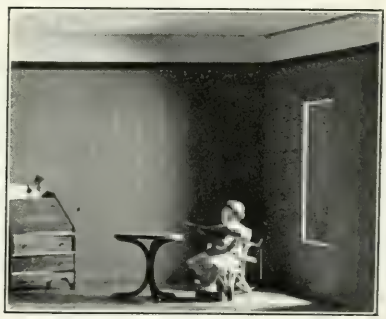
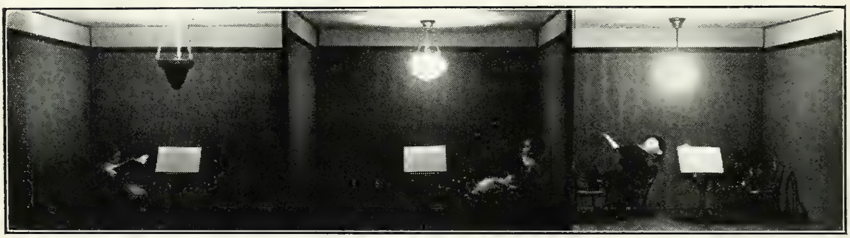


Fig. 9.—Daylight illumination.

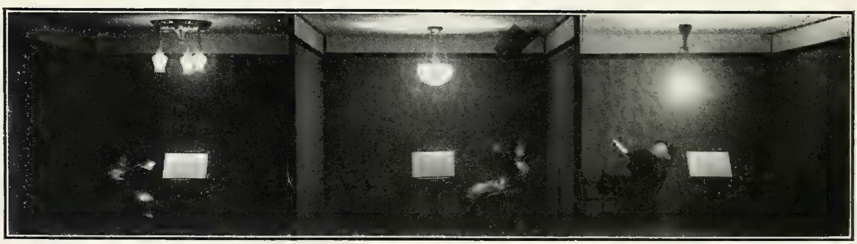
Room 3. Room 2. Room 1.

Fig. 11.—Semi-indirect lighting.



Indirect. Semi-indirect. Direct.

Fig. 12.—Three common methods of illumination.



Room 3. Room 2. Room 1.

Fig. 13.—Suggesting decorative or ornamental lighting units.

directs its light toward the ceiling. The rooms have been equipped with three ceilings—one is white, and has about as high a reflecting coefficient as is likely to be found in practise. Another is cream colored, and reflects a smaller proportion of the light. A third is dark cream, approaching a tan, and reflects still less of the light. This latter is about as dark as one might expect to find employed in an indirect lighting system, where any attention is paid to efficiency. Indirect lighting is so largely dependent upon the reflecting qualities of the ceiling, that the statistics of the illumination intensities in these rooms are of interest. The horizontal illumination intensity on the table plane averages for the three ceilings:

White ceiling	100%
Light cream ceiling*	87%
Dark cream ceiling	58%

showing a reduced efficiency of 42 per cent. due to the inferior reflecting qualities of the darker ceiling.

Following closely upon the development of the indirect lighting system, come systems classed inaccurately as semi-indirect lighting units, in which part of the light is reflected from the ceiling, as in the indirect system, while part of it comes directly from the translucent bowl surrounding the light source. It is obvious of course that with any translucent lighting auxiliary employed in a direct lighting system, some of the light which reaches the ceiling and walls, is reflected downward, and that the system is thus a semi-indirect system. Those units which are classed as semi-indirect units at the present time are, however, units designed especially with a view to directing a considerable proportion of the light toward the ceiling The most desirable combination of direct and indirect light for general purposes served by such units, is to-day a subject of discussion. Views of illuminating engineers vary in this matter. All kinds of relations between these two components are to be found represented by outfits now available in the open market. These range from equipments in which the transmitted light is so small a proportion

* It was discovered too late for correction that the light cream ceiling has diffusing qualities so unlike the dark cream ceiling that in spite of reasonably typical intensities on the table plane, the appearance as viewed from without the rooms is not consistent with the intensity figures shown; thus, the ceiling in Room 2, when viewed from the table, is much lighter than the ceiling in Room 3 though it does not so appear in the figures.

of the total as to make it apparent that the purpose to be served by the direct component is chiefly one of decoration, to those in which the direct component is so large as to make evident an intention to increase the efficiency considerably by restricting the amount of light which is subjected to the inherent ceiling loss.

In the photograph (Fig. 11) three semi-indirect lighting fixtures are shown. In room No. 1, a direct lighting reflector is inverted. In room No. 3, a bowl, not intended for this purpose, is employed. The design of its surfaces is not well adapted to this purpose, and it is therefore not so efficient as it might otherwise be made. In room No. 2 a hemisphere is utilized, illustrating semi-indirect lighting in the simplest of its characteristic forms.

It is a matter for gratification that illuminating engineers to-day have such an excellent choice as that afforded by the wide range of available equipments for direct, indirect and semi-indirect lighting systems. Each has its merits, each its demerits. In some installations, one type is preferable, in other installations, some other type may produce most desirable results. The good qualities which characterize each are coming to be incorporated, as far as practicable, in the others, and it may be noted that the more vigorously each system is exploited, the more beneficial upon lighting practise in general will the result be. With a direct lighting system, it is a simple matter to direct a relatively large percentage of the light downward upon say the table plane, but it is a difficult matter to so dispose the lamps and to so equip them that the installation will be free from troubles due to glare and shadow. With an indirect lighting system it is relatively a simple matter to avoid deleterious effects due to glare and shadow, but it is very difficult to direct a satisfactorily large percentage of the light upon the table plane. Where absence of glare and shadow is a consideration of paramount importance, an indirect or a semi-indirect lighting system may often be preferable, in spite of the necessity for somewhat greater expenditure in energy. Where these considerations are not so important, or where economy of operation is the prime consideration, a direct lighting system may prove preferable. In any case, the adroitness of the illuminating engineer may exhibit itself in

securing the best balance between economy on the one hand and absence of glare and shadow on the other. As to the appearance of the installations, there may be all kinds of diverse views, and we must remember that there is no disputing taste. Obviously it is difficult to discuss those phases of the question when dealing with the subject in a general way.

The three modern systems of lighting are represented in Fig. 12. In room No. 1, the direct lighting unit transmits sufficient light to make the walls pleasantly, but not objectionally, bright, while directing much of the light to the table plane. In room No. 2, the semi-indirect unit illuminates the card by light direct from the bowl and by light from the ceiling and walls in something like the proportions of 3 to 1. The relative direct and indirect components upon the table plane are of the order of 1½ to 1. In room No. 3 all of the light is diffused from the ceiling. The ceiling is the brightest surface within view, the lamp being entirely concealed. The illumination is very soft and uniform.

Comparing the two end rooms, it will be noted that in room No. 1, the vertical stripes in the wall-paper may be seen standing out clear and sharp. The character of the pattern is evident. In room No. 3 these stripes are seen somewhat less distinctly. This is due to the lower intensity of light on the wall. Still more important, however, as a factor, is the downward direction of the light from the ceiling. Viewed from the table, these stripes stand out distinctly as the angle and direction are then such as to be within the zone of strong specular reflection from the wall-paper. Viewed as in the photograph, these stripes can hardly be discerned except on the upper part of the walls near the border. The paper loses its character. This is an excellent illustration of the importance of securing proper direction from the major part of the light, although it should not be taken as an indication that the direction is wrong in this installation because it must be remembered that the effect would be minimized if the wall-paper were viewed from within the room, instead of from without.

With the conditions as established (and it is not claimed that they are more than suggestive of typical conditions) the card illuminations are as follows:

Room No. 1	220%
Room No. 2	100%
Room No. 3	42%

It must be remembered however, that the direct lighting unit in this case is favored, because the card is immediately beneath it at the point of highest intensity. For purposes of reading, as an example, it is difficult to judge from these figures as to the relative useful light. In the first place, questions of diffusion may result in establishing demands for higher intensities in one system than in another. This is one of the questions which is being very generally investigated at the present time, and in such a review as this, its discussion has no place. Dealing solely with the question of distribution, it may be noted that most reading would be likely to be done near the center of the room and that therefore the direct lighting system should receive some of the advantage in rating which the high intensity of the card immediately beneath the unit would appear to give it. The relative higher intensities in the corners of the room with the indirect, and to a lesser degree with the semi-indirect fixture, are not of much advantage from a practical standpoint. In this particular installation, with the same flux produced by the lamps in each type of lighting, the average horizontal intensities are relatively:

Direct lighting	1.61 foot-candles
Semi-indirect lighting	1.33 foot-candles
Indirect lighting	0.91 foot-candles

It is generally believed that with conditions suitable for each system of lighting, the direct lighting system will deliver about twice as much light upon the table plane as does the indirect lighting system, while each will illuminate the walls moderately.

The decorative feature has kept pace with developments in the other branches of the art. Lighting auxiliaries are consistently being improved in appearance, as well as in other features of effectiveness. Efficiency of reflection, the necessary degree of diffusion, and the proper direction of light are being achieved more and more completely as experience becomes greater. In good taste and other qualities that make for pleasing effects, constant advances are being made also.

The older lines of lighting glassware, including the prismatic, have been modified so as to render them more pleasing in appear-

ance while the addition of a number of new lines of phosphate and other glass affords the user a number of alternatives in the way of glassware equipment suitable for use with any given type of fixture in any ordinary installation.

In Fig. 13, may be seen illustrations of some of the more decorative types of fixtures and glassware now available in standard types. Whatever the character of the installation may be, it is more than likely that unless it is extraordinary, some fixture and some kind of glassware may be obtained which may be used in the installation with fair satisfaction. Unless installations are considered which are so unusual as to demand the design of special lighting equipments, those now obtainable must be considered to afford a very satisfactory range of selection.

The foregoing demonstrations must be taken with some qualifications. They do not pretend in all cases to be typical of any particular class of installation. Time has not permitted a thorough discussion of the characteristic qualities of any one of them. Appearances have been different from those which would have presented themselves had the rooms been observed from within.

The one thing which seems to me to have an immediate bearing from the central station standpoint, and which I hope is recognized is that if artificial lighting is to be made thoroughly good and satisfactory, it is necessary to thoroughly diffuse and otherwise modify the light which is produced by the lamps. This cannot be accomplished without considerable loss of light, and therefore entails greater consumption of electrical energy. Thus immediate commercial advantage goes hand in hand with good business policy and with altruism, when the central station spreads the gospel of good lighting among its customers.

DISCUSSION AT A MEETING OF THE NEW ENGLAND SECTION, MARCH 13, 1913.

Mr. A. E. Josselyn: I think Mr. Millar's demonstration has brought before us strongly the conclusion which probably many of us had reached in investigating complaints of poor lighting, viz., it is not so much a question of the light as it is of the lighting, the kind of glassware, fittings or the radiation of the light itself. It is not so much a question of the service supplied by the lighting company. In my experience, covering several years, we have many times been called upon to investigate what our customers claimed to be poor light and found, as a matter of fact, that the cause was poor lighting rather than poor light; that is to say the distribution of the light has been the cause of the dissatisfaction. In many cases this has been due to the location of the fixture or, if that has been located properly, it has been due to the fact that the glassware was selected more for decorative than for lighting purposes. I believe Mr. Millar's paper has brought out the fact that it is not so much the light as it is the lighting.

Mr. R. C. Ware: I think there is another point that is very strongly brought out along the lines just mentioned. We get complaints sometimes of poor light which is not only due to poor distribution but to the fact that the customer has insisted on using bare lamps. I think this very valuable demonstration of Mr. Millar's has brought out very clearly the absolute necessity of protecting the eyes; and that bare lamps mean the stopping down of the pupil of the eye to such an extent that the user does not get the full benefit of the light actually given off. This certainly ought to help us to talk intelligently and forcibly to customers who complain that they do not get results. We ought to be able to show them now why they do not, and to help them on to the road so that they may get what they are after.

Mr. J. W. Cowles: I judge that others are affected in the same way that I am to-night, in being somewhat over-awed by this paper in its many opportunities for discussion. What we have seen and heard has been brought out in such rapid succession that for my part I am quite bewildered in knowing just where to enter into the subject from a discussion standpoint.

There is so much that we have seen,—so many points have been brought out in a vivid and interesting manner,—that a considerable amount of careful thought is required for the proper digestion of the material offered. I have not as yet had an opportunity to read this paper in print, but my firm resolve to-night is to sit down with this paper in the quiet of my room, go through it carefully, and gain from it the profit that must come from the perusal and more gradual study of it.

PROF. GEORGE A. HOADLEY: I think one thing in the indirect lighting system should be taken into account, that is, the eye accommodates itself to the light in the room; you get the impression when first coming into the room, that the illumination is insufficient, but after having been in the room a short time, the illumination becomes sufficient. I might cite an example of the lighting of a dining-room in which an inverted cone shade was used which gave a spotty light on the table, and after putting a piece of ground glass across the bottom of the angle shade, the illumination became satisfactory.

DISCUSSION AT JOINT MEETING OF I. E. S. NEW YORK SECTION AND NEW YORK COMPANIES' SECTION OF THE NATIONAL ELECTRIC LIGHT ASSOCIATION, NOVEMBER 18, 1912.

Dr. Herbert E. Ives: The demonstration which Mr. Millar has given us this evening is, in my opinion, one of the most instructive ever given on the subject of illumination. We all realize from his use of dolls and toy furniture that this talk was meant to be of a kindergarten nature. Nevertheless I feel sure that I am speaking for all present, even those who in the words of the chairman have spent a lifetime studying illumination, when I say that we have learned a very great deal from his clear presentation and admirable demonstration. I wish to make no criticism of this, for it deserves nothing but praise.

Of course no one studying such a comparatively new subject as lighting will agree with everyone else. I would like to take this opportunity to emphasize a point which Mr. Millar could not, in the time at his disposal, treat. I want to call attention to the fact that in all these demonstration booths the light source is a centrally overhead fixture. We are so accustomed to such a system of lighting that I think we are apt to overlook the fact that it is not the only possible method and perhaps not even the best. The other evening there was a paper presented at the Philadelphia Section of the Illuminating Engineering Society on indirect lighting, and one remark made by the speaker was to me very suggestive. He said that all of the fixtures used were placed on the outlets which had been "planned by the contractor." It is a question in my mind whether we have not reached the point where we must go beyond the contractor and his ideas. For instance, may it not be possible that the light of the future will be from the side rather than from overhead? The lighting of a room by daylight is from the side and is generally considered pretty satisfactory. It differs, too, from most artificial lighting in the size of the light sources.

Mr. Millar has followed the usual classification of direct, indirect and semi-indirect lighting. To my mind, however, the proper classification is on the basis of the size of the sources.

We have been accustomed to small light sources which are necessarily of high intrinsic brilliancy, and we are now working towards larger sources of lower intrinsic brilliancy, whether it be by the use of translucent diffusing media or by diffusive reflecting material on the ceilings. In the illumination of most rooms by daylight we have a very large light source, namely, the sky, which at the same time is usually not visible to a person in the room who looks out at the neighboring houses or at the lower portions of the landscape. The net result is illumination from a large invisible light source from which the general direction of illumination is at the side. I hope to see experiments made with a view to meeting these conditions by artificial light. I feel sure they will be instructive and they may lead to some satisfactory systems of artificial lighting.

Right in line with Mr. Millar's concluding remarks I may say that according to all present indications if we do copy daylight illumination in the manner I have suggested it will mean the use of an enormously greater amount of electrical energy or gas.

Dr. C. H. Sharp: I feel very much as Dr. Ives that there is much to be said in the way of praise about what we have seen here to-night. I have known for some time that Mr. Millar had in preparation a demonstration of light in miniature, and I have been wondering, without knowing anything about it, what he could make out of it. How could he show to us lighting effects in rooms which we are not inside of but which we are merely allowed to look into and give us any adequate idea of what is really the effect inside those rooms? My questions have all been answered. I can say that he has been able to show us a great deal regarding practical conditions of illumination.

I agree with Dr. Ives regarding daylight illumination. I think it is pretty good, and one reason why it is good is because there is plenty of it, and if there is not plenty of it it is not good. Under the usual New York conditions we are not often much affected with the glare from the sky. We do not see the sky, but we do get a thoroughly diffused light in the room which is sufficient in amount but which is directed. Now I think that it might be possible to work out something in artificial illumination to simulate daylight illumination. Imagine

you have around each window of the room, say, a trough reflector with a lot of lamps so directed that if they were turned on they would throw light out of the room. Now when night comes on and light ceases to stream in through the windows, we draw down over the window a very white window shade, opaque, and with a very good white surface, and then turn on the lights. Then the lamps will throw a strong illumination on the window shade and which will throw it back into the room directed and diffused and distributed similarly to daylight. There should be less glare than there is in daylight. This would have another advantage in that if the office furniture and the arrangements of the room in general were made so as to be most advantageous for daylight illumination, they would also be the most advantageous arrangements for the night time. I have not made any computations on this as to the number of watts per cubic foot it would require, but I have no doubt that the plan would be practicable in certain cases even if the efficiency were not very high. It could hardly be more extravagant than other indirect systems.

Mr. L. B. Marks: As I heard Mr. Millar talking this evening I recall a letter which I received about two years ago from Dr. Ives in which he suggested that I make similar demonstrations at the Johns Hopkins University in Baltimore in connection with my lectures on principles and designs of interior illumination; but I was afraid to try it. I did not have the nerve Mr. Millar has. As I sat here this evening and heard his lecture and viewed the demonstrations of the principles discussed by me at Baltimore, I felt convinced that anybody who had the good fortune to see the demonstration which Mr. Millar has prepared would receive an object lesson in illumination which I believe would be far better than any theoretical discussion of the subject.

With regard to the question that was brought up this evening of producing a distribution and direction of light similar to that of daylight, I have a somewhat different view than that expressed by the other speakers. It seems to me that it is desirable to have a change at night. We all want a little variety. We do not want to eat the same dish at every meal, breakfast, lunch and dinner.

For daylight illumination we must depend almost exclusively on side windows. It is a fact that we cannot plan the best day-

light illumination because of the physical limitations of buildings. We usually have a number of floors in each building and cannot get a desirable distribution of light in all of them, if indeed in any of them. We have not that limitation at night. Then why not avail ourselves of the broad scope of application we have in electric and gas lighting? If you discuss this matter with the architect or with the decorator he is likely to tell you he can obtain much more pleasing effects at night by artificial light than he can in the day time, because he has the ability to place the light sources where he wants them. One of the criticisms which Mr. Edward Caldwell the distinguished fixture designer and decorator made of my lectures was that I did not lay sufficient stress on the importance of changing the character of the illumination at night. In his opinion that constituted one of the important things that an illuminating engineer has to study up—the arrangements of various lights and shades and the production of pleasing effects at night, not possible by daylight.

There is another matter which I want to speak of briefly, namely, Mr. Millar's closing remarks with reference to the greater use of light. In the I. E. S. Primer which was distributed this evening the principles underlying nearly all of Mr. Millar's demonstrations are discussed and illustrated. The keynote of this Primer is good diffusion of light. What does good diffusion of light mean? It usually means more light and better light. I hold that it is up to the illuminating engineer if he finds it necessary to recommend more light to do so and to do so fearlessly, even though the customer is told he must pay more money for it. One of the first things that the lighting company's representative will be up against when the public calls for greater diffusion of light is the complaint that the lighting bills are larger. We have seen here to-night a demonstration which will convince any man—and what is more important any woman of the household—that it pays well to use more current or gas for lighting if you can get better results in diffusion of light.

It would not be a bad idea to get out a miniature exhibition set of this kind that the salesman or company's representative could take with him to make a demonstration to the housewife.

Mr. D. McFarlan Moore: Mr. Millar has laid before us a wonderful wealth of ideas. We can hope for some future

paper to carry out in greater detail some of the modifications of his general scheme that suggest themselves. But I admire the thoroughness with which he has worked out the equipment details of his three demonstration rooms.

In these days we hear a great deal about direct, semi-direct and indirect lighting. Still better diffusion is continually desired. Indirect lighting virtually consists in changing a point source to the entire ceiling as the source of light.

I have been introduced as the inventor of the Moore light. We should not forget that one of the solutions of this problem of better diffusion is to directly increase the area of the light source itself, abandoning the intense light of bulbs for the soft light of long tubes, thereby also avoiding the necessity for any form of reflecting or diffusing or softening glassware, but using the light directly at the intensity at which it is generated.

Dr. A. S. McAllister: I have nothing to say in addition to the remarks, except that I wish to compliment Mr. Millar on his excellent demonstration, the thoroughness of it, the accuracy and fineness of the work, etc. The subject of light from the aspect which Dr. Ives spoke of is one to which I have given some little thought. I do not quite agree with him that we want the light on the side. In order to get it on the side we must place it in the line of view. Now I do not care how much it diffuses, we must have a little of that, and that to my mind is not objectionable. I am inclined to think that light above is oftentimes more advantageous.

Mr. C. A. Littlefield: I wish to express to Mr. Millar personally and on behalf of the section my appreciation of the wonderful demonstration he has given us this evening. Its chief advantage is that it is so complete and comprehensive, yet so simple and devoid of uninteresting technical detail. To my mind one of the most successful things the Illuminating Engineering Society has done, from a popular standpoint, is the publication of the Primer. If in some manner this lecture and the Primer could be made integral parts and be presented in various parts of the city and country a vast amount of good could be accomplished. We all know that very little is known of correct lighting principles, and even

in my own home I know that lighting conditions are not as they should be, but could this lecture be given before popular audiences, in churches, lecture halls, etc., it would get before the public generally a knowledge of correct lighting fundamentals that would do an enormous amount of good. It is too good to be kept merely for technical societies and meetings, and I trust that some way may be found whereby this plan can be carried out. I feel that this must have been one of the motives that animated Mr. Millar to give such an enormous amount of his valuable time to prepare this lecture. Mr. Millar is too well and favorably known among the profession to need any eulogy from me, but a public delivery of this lecture would much enhance his reputation and at the same time do a great amount of good.

Mr. Norman Macbeth: There is very little I can add. I consider the demonstration Mr. Millar has made here to-night one of the finest things I have seen in a long time. His methods of showing the wonderful detail work of the various sections of these rooms, the smoothness of the stage work, and his lecture itself are remarkable. I believe a great many people here have an entirely different idea of the lighting question after seeing Mr. Millar's demonstrations.

Mr. A. J. Marshall: I wish to express my congratulations to Mr. Millar on his most clever, instructive, and entertaining demonstration, which I feel privileged to have been able to witness.

I am a very great believer in catering to the brain through the eye in educational work, and consequently am the better able to appreciate the character of Mr. Millar's elaborate and painstaking experiments.

It would seem unpardonable to criticise the effects that we have witnessed this evening on account of their general all around value. However, I would like to state that none of the interiors which we have seen, to me represent good practise in the lighting of living rooms. As a matter of fact, I certainly would not employ any that I have seen. Most of the effects shown are those associated with the past or with what might be termed inappropriate "mechanical" lighting equipment, which

certainly does not represent good practise, or which has the support of architects, fixture houses, up-to-date central stations, gas companies, the public, etc. In fact, it is just the equipment as shown that advanced workers are eliminating.

This, however, should not be considered as being uncomplimentary to Mr. Millar in any way, shape, or form. The criticism is directed simply to equipment which is to-day not considered good practise.

The interesting phase of the whole matter is that something has been done, and Mr. Millar should be complimented upon his success in doing that something exceedingly well.

Mr. A. W. Stark: I am very glad to tell you that I was very much impressed with Mr. Millar's lecture. I think, however, that Mr. Millar omitted a very important subject in connection with his lecture, and that was the quality of the light. I agree with Mr. Marks, who spoke a moment ago, that we need a variety at night. If it is possible to distribute light in a better manner than comes through window openings from different floors of the buildings that we have to occupy through the day, such an arrangement is much more desirable. However, the quality of the light is vitally important. In looking around I think it safe to say that 25 per cent. of those here are wearing glasses. Why? I think that if we had somebody present who knows more of the subject than I do he would probably say they have misused their eyes. I think that fact is generally due to not only misusing the eyes, but that the quality of light was not best for the eyes. Daylight will not affect as seriously, if properly used, the eyes, as any artificial light. I would have been very much more pleased with what Mr. Millar had to say if he had given us a demonstration of what gas light would do.

Mr. C. B. Graves: The question of indirect lighting and low ceilings probably enters more into residential work than in any other work. It is simply a matter of distribution, and in that case the fixtures must be suspended within a distance of some 14 or 18 inches from the ceiling. Very good results are obtained from low ceilings, as it simply means a matter of a larger number of fixtures for the area to be covered. I think that where there is room for clearance, that is, where a ceiling of 8½ to 9 feet high is available, that indirect lighting can be worked in

very successfully, and in fact it has been done in a great many cases.

Mr. Preston S. Millar (In reply): I could myself also mention a few things that have been overlooked in these demonstrations. We have the necessary equipment. We have a definite schedule for about 40 demonstrations, and we have presented 12 in a period of one hour and a quarter; 40 would take six hours. We did not present the others.

ILLUMINATION AND EYESTRAIN.*

ELLICE M. ALGER, M. D.

Synopsis: In this paper the following topics are discussed in the order given: Nature of eyestrain and the part played by illumination—Daylight the ideal illuminant—The composition of artificial lights and the effect of the short waves in producing discomfort and disease in the eyes—The intensity of light and its lack of diffusion as factors in ocular fatigue and inefficiency—The relation between poor lighting and industrial accidents—The arrangement and position of lights and their influence on efficiency—Experts agreed on the general principles involved in good lighting, but not on the details—Education and discussion must precede any drastic legal regulation.

Eyestrain is the common expression for that rather comprehensive group of symptoms which result from abnormal ocular fatigue. It results from compelling eyes to do work which is beyond their physiological capacity. Things close at hand are seen by a muscular effort of focussing which, when long continued, produces a normal fatigue and requires a definite period of recuperation. If the eyes tire sooner than they should because of some intrinsic weakness of ciliary muscles, or because of a handicap imposed by astigmatism or increasing years, the fatigue is apt to manifest itself not only by defective vision but by pain, and we speak of the condition as an accomodative asthenopia. The eye likewise sees things through the effect of light falling on a sensitive retina. If this light be over bright, or if the retina by reason of over-exposure or disease is hypersensitive, the result is the disturbance of vision and pain which we call retinal asthenopia. The results of eyestrain are manifold and affect no two people exactly alike. They include pains in the eyes and many functionl defects of vision and, quite possibly, often result in organic eye disease as well. They cause 80 per cent. of the chronic headaches. They often result in functional disturbances of other organs and in conditions of general nervous exhaustion and irritability. While most of the symptoms that come from eyestrain are of the accomodative sort, these are all capable of aggravation by improper lighting and there are so many that are

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caused directly in this way that I shall invite your attention for a time to the relation between eyestrain and illumination.

In studying this relation it must be remembered that there are few exact standards of ocular capacity. The average individual can see objects of a definite size at a definite distance and this average is taken as a standard, but there are many who fall below this standard without obvious cause, and many who are far above the average. The variations in muscular endurance are still wider and one man can work hour after hour at tasks which fatigue another in a very short time. The sensitiveness to light likewise varies widely in different individuals, both ability to see distinctly by faulty light and ability to work without exhaustion in strong light.

Light is the reaction excited in the retina by the impact of certain vibrations or waves in the ether, which cause different sensations according as they are longer or shorter. The long ones give the sensation of red light, while, as they get shorter and shorter, one may see in succession all the colors of the visible spectrum. The mixture of all these wave-lengths together produces the sensation of white light. But the visible spectrum does not include all the waves by any means. There are longer waves than the red which cannot be seen but can be felt as heat, and shorter ones than the violet which have a very active chemical effect. It must be remembered too that both these qualities exist in the visible spectrum, the heating effects predominating at the red end, while the violet end approaches the ultra-violet in its chemical activity.

This enables one to explain some of the untoward effects of daylight on the eyes, even though daylight affords the best illumination for ordinary purposes.

Many of the effects of sunlight which were once attributed to heat are now known to be due to chemical activity. For instance, in snow and desert blindness the light is broken up by reflection from the crystalline snow or sand, and the actinic waves produce intense inflammation of the conjunctiva which, if long continued, results in total disability. Even in temperate climes one suffers more or less from glare and burn from direct or reflected sunlight, and by common consent a good north light is taken as the standard of ideal illumination, being the steadiest, the pleasantest

to the eyes, the best diffused, causing the fewest shadows and affecting color values least.

An artificial light can be broken up into its component parts and its spectrum compared with that of daylight, and its illuminating power can be measured by aid of various photometers; but so far there is no artificial light which is just like daylight, though we are said to be getting nearer and nearer to it.

It has been shown by experiment that the light which gives the maximum of illumination with the minimum of irritation of the eye is composed of the yellowish rays from the middle of the spectrum. For this reason the old fashioned candle and kerosene lights have never gone entirely out of fashion. But most of the more recent artificial lights, whether gas or electric, contain a much higher proportion of the short violet or actinic rays and some of them contain many of the ultra-violet rays as well. When unshaded their chemical activity is so great that they can be used for various therapeutic purposes. They are capable of tanning the skin, and of causing symptoms like those of a modified snow blindness. Prolonged exposure to the electric arc light sometimes produces an intense conjunctivitis with contraction of the pupils and erosions of the cornea, which fortunately generally yield readily to treatment. Nearly everybody has experienced the discomfort and premature fatigue that comes from reading by unshaded incandescent lights. Even if they do not actually produce inflammatory changes themselves, they certainly render those already present decidedly less tolerable.

It is quite possible, however, that the delayed actinic effects of light whether natural or artificial are much more serious. The ultra-violet rays are arrested by ordinary glass, and in the eye by the tissues of the cornea and lens so that the deeper structures of the eye escape harm, but there is strong reason to suspect that their constant absorption by the lens may be one of the causes of cataract. Experimenters have been able to demonstrate lenticular changes in the eyes of rabbits exposed to such lights; and it is known that stokers and glass-blowers, who have to face very brilliant incandescent light, have a tremendous predisposition to cataract. This so called bottle-makers' cataract begins not in the anterior part of the lens, which would be expected if heat were

the essential factor, but in the posterior portion where the rays of light are most concentrated. Other suggested observations are that in the ordinary cataract of old people the first changes generally occur in the lower inner quadrant of each lens, which is the part least shaded by the brows and so most exposed to sunlight from above, and that when cataracts develop in people who have one light and one dark eye, it invariably appears first in the one unprotected by pigment from the light.

Even if the ultra-violet rays do not reach the deeper structures of the eye, one must not forget that the shorter waves of the visible spectrum have decided actinic properties. Many people have had their eyes permanently ruined by incautious watching of an eclipse, and similar damage sometimes follows exposure to electric flashes and even to long exposure to the arc light. In such cases the light is condensed on the surface of the retina resulting in local inflammation and degeneration, that particular spot becoming permanently blind.

Oculists suspect, though they cannot prove, that less intense and longer continued light irritation may be a factor in many similar degenerative changes in the retina and chorioid, and advise both for prophylaxis and treatment the use of amber glasses, and shades of such composition as to soften the light and exclude the actinic end of the spectrum. To people who are at all sensitive to light they are a great comfort.

Our north light is soft and even and well diffused, so that it causes a minimum of shadows. Artificial light to give anything like the same amount of illumination must be much more concentrated and intense. Now the human eye even in natural light has to adapt itself to so many variations of intensity and dimness that it has developed a very beautiful mechanism for regulating the amount of light admitted to the retina. When the light is dim the pupil dilates, and when it is bright it contracts sharply. A sudden very bright light causes pain not because the retina hurts but because of this sudden extreme muscular contraction of the iris. Constant exposure to bright light necessitates constant muscular contraction and engenders in many people premature fatigue. Still more tiresome and painful is the rapid dilation and contraction of the pupil that results from the varying intensity of a

flickering light. Furthermore, intense and long continued exposure to bright light causes retinal exhaustion and the retina is capable of reacting only to powerful stimulation. In other words, that retina becomes for the time being blind except in the brightest of lights. Every one has experienced the comparative blindness caused by going from bright sunlight into a dimly lighted room. It is a common experience to have workmen insist on having as intense a light as possible because they have temporarily so blunted their retinal sensitiveness that they are helpless without it, and it is generally the hardest kind of a task to convince them that even if they suffer no harm from the glare they cannot possibly work as long without fatigue. In another set of people the retina instead of being blunted becomes hyperesthetic and finally almost incapable of bearing any exposure to light at all. This condition is seen at its worst in hysterics, when it is of course not a result of over lighting, but there are a number of occupations like those of the gilders and polishers who have their attention fixed for long periods on bright surfaces, in which retinal asthenopia is very common.

Furthermore, daylight has a vast volume and is diffused so that objects get light from all sides, and shadows are reduced to a minimum. Artificial light can hardly be expected to secure thorough diffusion and more than comparative freedom from shadows, but in many industries almost no attention has been paid to this point. And yet it is very important, for Calder in a very interesting paper has shown that the retinal anesthesia and deep shadows that result from poor artificial lighting are potent factors in causing industrial accidents. The records of some 8,000 manufacturing plants over a period of three years showed a regular minimum of accidents during July and August which gradually increased to a maximum in the dark winter months. The influence of daylight in preventing accident was much more evident in occupations which require not so much bright light as diffused light without shadows over large areas as in the building trades for instance. Indoor workers as often suffer accident from too much light as from too little. Exact photometric measurements often show that the light of ordinary incandescent lamps concentrated at the cutting point

of a tool or a work-bench is often several times the intensity of daylight. But the eye adopts itself to this intensity and when the workman turns from his over-lighted work, perhaps in a room full of moving machinery, he is practically blind. What is needed from the point not only of safety but of health and comfort is much less intensity and much better diffusion of light. This applies to all walks of life. We have all become accustomed to using far more intense light than we need.

One can measure the amount of illumination, by photometers which are much more accurate and dependable than the human eye; but, after all is said and done, the eye is one of the best of photometers if one is careful not to injure it in the process, since it is upon its adaptability to that eye that all artificial lights must stand or fall. One should begin with a low illumination and gradually increase it till a point is reached when further increase ceases to improve the details of the work in hand. Beyond this all additional light is both unnecessary and physiological extravagance.

Abnormal fatigue is admittedly one of the greatest predisposing causes to most diseases be they physical or mental, and though the part played by bad lighting is perhaps not clear cut it is beyond doubt. In most factories, schools and offices the eyes must be used constantly for work of a character they were never intended for. The result even in normal eyes is a muscular and nervous fatigue which is measurably increased by both over or under-lighting. The first engenders fatigue from retinal exhaustion and pupillary spasm, while the second results in the strain that follows sharp focussing and constant attention. In the majority of individuals whose eyes are handicapped by astigmatism or other refractive errors, the strain is still greater. I shall not take your time with the long list of conditions of health which have been attributed to eyestrain. Some of these are beyond dispute, others are still in question.

The over-lighting which is so common to-day may conceivably have other effects. Woodruff has shown that in the tropics blondes who are unprotected by skin pigment are over-stimulated by the bright light and finally develop a characteristic nervous exhaustion. It is quite possible that eyestrain and the constant exposure to intense light of short wave-length may be predis-

posing factors to the neurasthenia from which our garment makers admittedly suffer.

The arrangement of lights as well as their composition and intensity is of importance. It is well known how uncomfortable it is, and how much it interferes with clear vision to have a bright light shining directly into the eyes, and lights which enter the eye from below are much more annoying than those from above. And yet how often are machines so placed that the operator has to face a window or a light. The same difficulty occurs in trades like those of the gilders and polishers who have bright lights reflected into the eyes from their work, and in schools where the smooth shining pages of the books answer the same purpose. So far as possible light should fall from above, behind, and to one side. The light should be sufficient for the work in hand, should throw no shadows on the work, and should be reflected, not into the eyes of the workers but to one side. When it comes to the arrangement of light for many workers in a factory or school the problem is very much more difficult and presents many technical details, which must be left in the hands of the illuminating engineer.

Even when estimated by its actual cost in dollars and cents, bad lighting is often more expensive than good, but from the standpoint of efficiency there is no comparison. Bad lighting undoubtedly causes unnecessary strain of the eyes and consequent premature muscular fatigue; it compels closer and more constant attention to the details of work, so that tasks which should be done almost automatically and without mental effort are done consciously. Under such circumstances the output of each individual is manifestly less than it should be, there is a larger percentage of mistakes and material spoiled, and the number of accidents, large and small, is vastly increased. Even under the best of conditions, the extreme subdivision of factory work with its consequent monotony, largely destroys the pleasure of work, but bad eyes and poor lighting and long hours are important factors in the industrial discontent of the day.

It goes without saying that any system of scientific shop management worthy of the name implies a good lighting system as one of the first requisites, but as yet opinions vary widely as to just what this means. It is possible to regulate the color and

composition of the light that enters the eyes by the interposition of screens or shades which shall absorb the rays one does not wish to use, or by having it reflected from suitable colored surfaces. The volume and intensity of light can be regulated by increasing or diminishing the number of units, and by diffusing it with frosted shades, or by reflecting it from rough surfaces. But while the experts are agreed on the principles involved they do not agree entirely on the details. The human eye is flexible enough to adapt itself to very wide variations in illumination but there must be comparatively narrow limits within which the greatest efficiency may be reached. Quite possibly different industries may require entirely different types of illumination and while these may be worked out in detail in the laboratory they must all be subjected to the final test in the shop or school.

Illumination as a science is yet in its infancy. Even in great public buildings, libraries, and theatres it is treated not as an essential but simply as an aid to the proper display of the genius of the architect or the taste of the decorator. And if such buildings are badly done one can hardly expect as yet that any great attention will be paid to the proper lighting of the ordinary factory or house.

Every one admits to-day that the state must control factory conditions so far as they effect the health and well being of employees and many attempts are being made both here and abroad to deal with the subject of illumination by law.

It is an extremely difficult subject to handle in this way; even the experts are not agreed on many important points. What would be good lighting in one industry might be the worst possible in another. To make drastic regulations in the present state of the art would often involve manufacturers in great expense in changing their light equipment without any guarantee that it would be permanently satisfactory.

After all, good lighting is essential to the efficiency of both employer and employees, and a judicious campaign of education will make them both appreciate it. Then too, there are numerous large and powerful corporations engaged in various branches of the lighting industry and there is perhaps little danger that the subject will be allowed to be forgotten either by consumers or legislators.

DISCUSSION.

Dr. Percy W. Cobb (communicated): Dr. Alger has said that there are few means of measuring ocular capacity, to which I would add "which are of practical use in the question of illumination."

To the ophthalmologist the test-types are familiar, by which the size of the smallest type that can be read furnishes the basis on which visual acuity is measured. Among other means of estimating the capacity of the eye, one is by its perception of small differences in brightness in fairly large surfaces—to be distinguished from visual acuity estimation, where the brightness-difference between object and background is large and the size of the object seen is minimal. Similarly the color sensitivity of the eye can be measured and many other criteria of the sensitiveness of vision have been worked upon, but never made practical for the purposes which concern illuminating engineers. That branch of physiology is as yet in its infancy.

The major disturbances of the eyes, such as ophthalmia electrica, snow blindness, occupation cataract and the like, probably due to the ultra-violet radiation, are however quite frank and to the ophthalmologist easily recognizable. A noteworthy point is that these disturbances all have their origin in conditions far removed from those of customary illumination. On the other hand, the troublesome minor and more familiar disturbances which appear in the use of ordinary illuminants (headache, smarting of the eyeballs, blurring of vision and so on) seem to take place under conditions such that physical considerations practically preclude the ultra-violet radiation as the cause; for we know that the light from an ordinary tungsten filament is, for equal visible light, far poorer in the ultra violet light than daylight, and is used at illuminations almost incredibly lower than those that obtain in daylight conditions. With a good daylight illumination in a room, turning on the artificial lights makes almost no impression on the eye, indicating how relatively low the artificial illumination really is.

It is another matter when we come to consider such a thing as a light source in the visual field. Here we have an intense focussing of energy upon a minute area of the retina, and a disturbance

soon results, as anyone knows who has glanced at a naked filament for a second or two and noticed the after images of it which subsequently disturb his vision. Whether the ultra-violet plays a part, this is an open question. We must remember that the preponderance of the visible radiaton is extremely large in cases which the illuminating engineer has to consider.

Bearing on this point is some work quite recently published by Dr. Ferree, from which it appears that the eye suffers a considerable loss in power from work under a system of artificial illumination, of which a number of the sources come within the field of vision. The loss in the power of the eye appeared not in the acuity itself, as the eye was able to see equally small test-letters after the period of work, but in its ability to maintain that power; the identical test-letters viewed after the work-period showed a greater tendency to appear blurred at times.

Apart from high intrinsic brightness of objects it seems much more than probable that widely unequal illuminations in different parts of the room can induce retinal disturbance and eye-strain. The writer is inclined to explain the minor eye-disturbances just mentioned largely on this basis. The eyes working in an overdone local illumination, on a bright page or a machine with its numerous reflections, are turned to relatively dark places, for which they are wholly unadapted, and back again to the intense light—for which by that time they are again unadapted. It is not hard to imagine how such conditions can induce retinal fatigue and muscular eye-strain. A more tangible loss due to such a system is the economic value of time wasted in fumbling for a needed article in a dim light with bright-adapted eyes; and above all the danger of accident, especially in manufacturing plants, to persons obliged to move about in relatively dim surroundings in which their eyes, recently under high illumination are more or less blind.

For such reasons legislation as to illumination conditions in factories, schools and other public and semi-public places is an important part of the modern movement for the conservation of human resources, and it can be expected that such legislation will progress whenever experts in illumination can make it clear ex-

actly what is the most efficient lighting, when all things are considered.

Dr. Sinclair Tousey (communicated): The paper is remarkably complete and accurate.

Eye-strain is much more commonly a result of imperfection in the eye, than in the light. The muscles which regulate the size of the pupil for the amount of light, act automatically and practicably without fatigue and provide for a wide latitude in the intensity of illumination. Where eye-strain is diagnosed it is not enough to correct errors in illumination, but the eye itself should be tested as to accommodation or focussing power, as to astigmatism or difference in curvature and refractive power along different meridians of the eye, and as to the ocular muscles which should be so accurately balanced as to automatically direct both eyes toward the same object without fatigue.

The ultra-violet rays are much more abundant in sunlight upon the mountain top, than in our cities where they have been filtered out by passage through additional thousands of feet of air and especially the dust in the air. Filtered water is more transparent to the ultra-violet ray than the air we breathe.

Dr. Alger is right in recommending glasses as a protection from sun-light upon snow-fields and in the desert and for electric arc lights; and it should be added that the worst accidents come from the blinding flash when an electric current is short-circuited and that these workers also should be protected by glasses.

Glass is practically opaque to the ultra-violet rays, but quartz or "pebble" lenses are transparent to them. Colorless glass is a complete protection from the invisible ultra-violet rays but of course if the luminous rays are too powerful, the colored glasses which give the greatest sense of rest, amber color perhaps, may be used.

I use glass in the measurement of ultra-violet content in light used for the therapeutic effect of those rays. The light from a mercury-vapor arc in a quartz tube may produce a certain effect upon a photographic film in a small fraction of the time required to produce the same effect through a thin piece of glass. Such a light will quickly produce a severe burn upon the healthy skin; and cures the terrible disease called lupus, but is manifestly un-

suited for ordinary illumination. A mercury-vapor light in a glass tube generates an equal quantity of ultra-violet rays but they cannot escape from the tube and have no harmful effect. The light from any electric arc is rich in ultra-violet rays and should always be filtered through a glass shade for illuminating purposes.

In applying my test for ultra-violet rays, it must be understood that no camera lens is used, the film or sensitized paper is exposed directly to the light. And any light which produces a markedly greater photographic effect through a sheet of quartz crystal than through a sheet of glass is regarded as too rich in ultra-violet rays to be desirable for illuminating purposes.

Professor Alger quotes Woodruff's statement that it is not the heat but the light in the tropics which injuriously affects the white races. This theory has been very widely tested and the general conclusion is against it. So that instead of the dark underwear advised by Woodruff, white clothing has been found to be better.

One other point should be mentioned and that is the eye-strain which inevitably results from a flickering light.

Eye-strain may frequently be prevented by the presence of a dimly lighted back-ground upon which the vision may rest during moments when the person looks away from his work. Constant staring at work at a fixed distance and with either too much or too little illumination, will cause strain in the best of eyes.

Dr. C. E. Ferree (communicated): Dr. Alger's paper is in brief compass an excellent and interesting symposium of the subject. The present writer has, however, the following comments to make.

(1) On the third page of his paper Dr. Alger says: "It has been shown by experiment that the light which gives the maximum of illumination with the minimum of irritation to the eye is composed of the yellowish rays of the middle of the spectrum. For this reason the old-fashioned candle and kerosene lamp have never gone entirely out of fashion." Although he willingly leaves himself open to correction, the present writer does not believe that the above conclusion can be justly drawn from the experimental evidence in existence at the present time. There are two

points to Dr. Alger's comparison: "maximum illumination" and "minimum irritation." Of these two points, so far as the writer knows, definite experimental work has been done only on the former.[1] By "maximum illumination" the writer asumes from the relation of the statement to the general subject of lighting that Dr. Alger means the maximum of illumination for seeing detail or maximum acuity of vision.[2]

There are two ways in which acuity of vision may be considered in relation to the problem of lighting: acuity as determined by the momentary judgment, and acuity which represents the average of ability to see detail for a period of time. Acuity as determined by the momentary judgment does not show the progressive loss of efficiency resulting from a period of work even under an unfavorable lighting system, because under the spur of the will the muscles of the eye, though they may have lost enormously in efficiency, may be whipped up to their normal power long enough to make the judgment required by this visual acuity test. Acuity, then, as determined by the momentary judgment can only be used to determine the general level or scale of efficiency for the fresh eye. It can not be used to detect loss of efficiency. In the problem of lighting, however, the general level or scale of efficiency as determined by the momentary judgment of acuity is, comparatively speaking, of minor importance. What is needed is a type of illumination that gives the highest average of acuity or efficiency in seeing for a period of work and at the same time the least loss of efficiency. So far as its relation to the quality of light is concerned, tests have been made up to the present time only of acuity as determined by the momentary judgment. With regard to this type of acuity Dr. Alger's statement

[1] Although no definite experimental work has yet been done on the effect of varying the quality of light on its tendency to produce discomfort, still it can be said from the results of our own work that when intensity and distribution are equalized, an installation of clear carbon lamps, which gives a light comparatively rich in yellow and red, shows a greater tendency to produce discomfort than an installation of clear tungsten lamps, the light from which contains a proportionately greater number of the short wavelengths.

[2] Visual acuity as usually tested involves the discrimination both of visual angle and of brightness difference. As it enters into seeing in ordinary life, it may involve also the discrimination of differences in color quality.

will be here examined in the light of the work done by three men selected as typical: Langley,[3] Luckiesh,[4] and Rice.[5]

Langley made his determination of acuity with the colors of the spectrum equalized in energy. Luckiesh and Rice, on the other hand, worked with colors equalized photometrically. Some again have exercised no especial intensity control at all. In the writer's opinion, Langley's conception is the correct one. We want to know for equal outputs of energy what color gives the greatest acuity of vision. To equate the colors photometrically is to equate them for seeing, which in a measure begs the question at the outset.[6] Langley, working with the light of the spectrum, showed that for equal amounts of energy (radiometrically determined) the maximal acuity of vision is given when light in the region of the green and blue-green is employed. His results, therefore, give no support to the belief that yellow light possesses an advantage over lights of other colors for clear seeing.

Luckiesh was not concerned primarily with making a comparison of the different colors for acuity, although such a comparison may be made from his results. His problem was to show that colors taken from a narrow region of the spectrum give greater acuity than colors more complex as to wave-length, and to find an explanation for this phenomenon. An examination,

[3] Langley: Energy and Vision, *American Journal of Science*, 1888, XXXVI, 3rd Ser., pp. 359-379.

[4] Luckiesh, M.: The Influence of Spectral Character of Light on the Effectiveness of Illumination, TRANS. of the Illuminating Engineering Society, 1912, VII, p. 135-158.

[5] Rice, D. E.: Visual Acuity with Lights of Different Colors and Intensities, *Arch. of Psychol.*, 1912, No. 20, p. 1-59.

See also Uhtoff: *Archiv für Ophthalmologie* 1886, XXXII, (1), p. 171. A. König: *Zeitsch. f. Psychol. u. Physiol. d. Sinnesorgane*, 1893, IV, p. 241; and *Sitzungsber d. Berliner Akad. d. Wissensch.*, 1897, XIII, p. 559; Pflüger: *Ann. d. Physik*, 1902, IX, p. 185; Oerum: *Skandinavisches Archiv für Physiol.*, 1904, XVI; Boltunow: *Zeitsch. f. Psychol. u. Physiol. d. Sinnesorgane*, 1907-8, XLII, (2), p. 359; Broca and Laporte: *Bulletin de la Societe Internationale des Electriciens*, Paris, 1908, VIII; 2nd Ser., No. LXXVII; Dow, J. S.: *London Ill. Eng.*, II, p. 233; Ashe, S. W.: *Electrical World*, Feb. 25, 1909.

[6] That is, visual acuity as ordinarily tested involves a discrimination of brightness difference as well as of visual angle. The discrimination of brightness difference sustains a relation both to the degree of illumination and to the color quality of the light. Up to a certain point an increase in the degree of intensity of illumination increases the discrimination of brightness difference. The presence of dominant color in the light, on the other hand, interferes with this discrimination or masks the difference. If, then, the colored lights are made of the same degree of luminosity as determined by the photometric judgment, there remains only one of the above factors to make them differ in the degree of acuity they produce, namely, the effect of color quality on the discrimination of brightness difference. Therefore, I have said that to make a comparison of visual acuity for the different colors with lights equated photometrically is in a measure to beg the question at the outset.

of his curves show a greater acuity for yellow than for any of the other colors of the spectrum. But a comparison can not be drawn from his results of acuity for yellow and white light; it can be made merely for yellow and the other colors of the spectrum. Moreover it is far from safe to pass from the results of his experiments to the conclusion that yellow light gives greater acuity than white light; and still less safe from a literal interpretation of these results to conclude that white light with yellow as its dominant hue, such as is given by the kerosene flame, gives greater acuity than is given by clear white light. Yet we presume that either results of this kind or results of photometric observations which strictly speaking are not applicable to the point in question, are responsible for the belief, somewhat generally held, that yellow light possesses an advantage for seeing over white light.

Theoretically speaking, this belief might at first thought seem to have considerable justification, for if white is made up of all the colors, and of these colors yellow gives the greatest acuity, then yellow should also, it might seem, give greater acuity than white light of equal luminosity. Too much would, however, be taken for granted in drawing such a conclusion, for as stated in the preceding foot note, visual acuity, as ordinarily tested, involves a discrimination of brightness difference as well as a discrimination of visual angle, and the presence of a dominant color in the light strongly interferes with this discrimination. In Luckiesh's experiments this color factor was present in case of each of the comparisons made. Moreover, it was probably weakest in case of yellow, for yellow is the least saturated of the colors of the spectrum. Hence, yellow in this regard possesses an advantage over all the other colors for the clear seeing of details executed in white and black, as is required in the visual acuity test. In the case of yellow vs. white light, however, the advantage is reversed. No color factor is present to reduce acuity in the determinations for white light.[7] In short, there-

[7] The difference between the results of Langley and Luckiesh was doubtless due to the difference in their method of equating their colors. Since Langley equalized his colors in energy, he had differences both in luminosity, and in saturation and quality of color to affect his discrimination of the brightness difference between his test object and its background for the different colors; while Luckiesh, since his colors were equated in luminosity, had only difference in color quality and saturation to affect this discrimination. Possibly resolving power of the lens should also be included as one of the factors influencing acuity for the different colors; but since the resolving power according to Rayleigh is greatest in the blue, resolving power could not at least have been a dominating factor in Luckiesh's observations.

fore, to reason without further experiment from results of the kind obtained by Luckiesh, to what would happen in case a comparison should be made for any of the colors and white light, as apparently has often been done, is to pre-suppose the assumption of a degree of simplicity with regard to the eye factors that does not exist.

Rice did not work with the light of the spectrum. He used the rougher method of isolating his wave-lengths afforded by color filters. He determined the acuity for light approximating white, (given in some cases by a carbon, and in some cases by a Nernst filament), and for the colors given by his red, green, and blue filters. These colors were made photometrically equal, each to each and to the white light. Ten different degrees of intensity were employed. The acuities for these lights were found to be in order from greatest to least: white, red, green, and blue. Yellow did not enter into the comparison.[8]

Even, then, with regard to acuity of vision as determined by the momentary judgment, it has not been established by experiment, so far as the writer knows, that either monochromatic yellow or white light predominantly yellow possesses an advantage for clear seeing over clear white light; and with regard to a visual acuity determination which represents an average for a period of work, no experiments have as yet been made which can be regarded as determining the effect of quality of light on clear seeing. In his own experiments the writer has planned to determine in order the effect of differences in distribution, intensity, and quality of light, both on the power of the eye to hold its efficiency during a period of work, and to maintain its maximum state of comfort. The effect of differences in distribution and intensity is now being worked out. The results for distribution have in part been published,[9] and more will soon be

[8] Oerum (op. cit.) also made a comparison of acuity for white light and the colors. He found white light to give the greatest acuity. Of the colors, red, green, and blue, red gave the greatest; green next; and blue the least. Boltunow (op. cit.), however, making a similar comparison, found green to give the greatest acuity of these three colors, and red the least. White gave a greater acuity than any of the colors. Ashe (op. cit.) determined the acuity for red, green, blue, and white lights of equal luminosities. He found the greatest acuity for white lights. Of the colors, blue gave the greatest acuity, green next, and red the least. Dow (op. cit.) found that light in the region of the blue-green gives the greatest acuity for near objects, and light in the region of the red for distant objects.

[9] C. E. Ferree. Tests for the Efficiency of the Eye, etc. TRANS. I. E. S. (Jan., 1913), vol. VIII,, p. 40.

published. A systematic study of the effect of differences in quality has, however, not yet been undertaken. The writer is, therefore, not at this time in a position definitely to commit himself on this point. He can say, however, from the results of the work already done, that with distribution and intensity equated, an installation of clear carbon lamps, which gives a light relatively rich in red and yellow, causes the eye to fall off more in efficiency as the result of a period of work than an installation of clear tungsten lamps, the light from which is whiter and contains proportionately more of the shorter wave-lengths. In short, it is the writer's contention that the question whether or not white or colored light is better for the eye can not be answered until definite tests are made of this point alone under conditions in which all other factors are rendered constant. The merits of the kerosene flame, for example, as compared with other sources of illumination, must be tested under a system of installation that gives the same intensity at the source and, as nearly as possible, the same distribution in the field of vision as is given by other illuminants. This has not been done at all. Our judgment of the comparative merits of the color quality of the light given by it are based on the roughest kinds of impression obtained under conditions of installation in which there has been no attempt at control of the other factors that influence the effect of light on the eye.

(2) On the sixth page of his paper Dr. Alger says: "One should begin with a low illumination and gradually increase it until a point is reached where further increase ceases to improve the details of the work in hand." That is, visual acuity is here made the test of the amount of light that should be employed. But, as is stated above, visual acuity, that is visual acuity as determined by the momentary judgment, is not the only or even the most important factor that has to be taken into account in lighting. The element of time must be introduced into the test. That is, an intensity of illumination must be chosen at which the eye holds its maximum acuity or efficiency for a period of work. This is by no means in every case the same degree of illumination that gives the maximum of acuity as determined by the momentary judgment. For example, our tests for loss of efficiency for different intensities of illumination with a given

type of installation do not show that the degree of illumination that gives maximum acuity for the momentary judgment gives also for every kind of installation the least loss of acuity or the maximum average of efficiency for a period of 3-4 hours of work. Moreover, the comfort of the eye must also be taken into account. Here also results are wanting to show that the degree of illumination that gives maximum acuity as determined by the momentary judgment gives also maximum comfort. In short, the degree of correlation between visual acuity, loss of efficiency and the tendency to produce discomfort can not be taken for granted. These factors constitute three separably determinable moments, no one of which should be neglected in installing a lighting system.

(3) Dr. Alger says on the eight page: "The human eye is flexible enough to adapt itself to very wide variations of illuminations, but there must be comparatively narrow limits within which the greatest efficiency may be reached." Our work on the effect of varying the intensity of illumination on the eye's loss of efficiency shows that in general this statement is true. The range of favorable intensity varies widely, however, with the type of installation. It is, for example, much narrower for the direct than for the indirect lighting system.

(4) On the seventh page Dr. Alger says that "lights which enter the eye from below are much more annoying than those from above." This statement is also borne out by the results of our experiments. In making a preliminary study of the causes of discomfort, a light of constant intensity was thrown on the retina at different points in its several meridians, and the time limen of discomfort was determined. This limen was found to be lower for the upper than for the lower half of the retina; and for the nasal than for the temporal half.

(5) On the fourth page Dr. Alger says: "A sudden very bright light causes pain not because the retina hurts, but because of a sudden extreme muscular contraction of the iris. Constant exposure to bright light necessitates constant muscular contraction and engenders in many people premature fatigue." Magendie's experiments in 1824 showed that the retina and optic nerve are insensitive to pain from mechanical stimulation. These

and similar experiments have led to the belief that the discomfort experienced on exposing the eye to a degree of illumination to which it is not accustomed is muscular. That it can not be wholly or even essentially muscular is shown by the fact that it is gotten in cases where the ciliary and iris muscles have been paralysed by atropin; also in cases where the lens has so long been removed that muscular atrophy must have taken place. In short, there is no doubt in the present writer's mind that the discomfort experienced as the result of work under unfavorable conditions of lighting is not by any means all muscular. The "sandiness" passing over into a stinging stabbing pain which comes early in the experience of discomfort seems to be conjunctival. Just what other reactions come as the result of exposing the retina to a degree or kind of illumination to which it is not accustomed is for future work to determine. That they can not all be muscular is plainly obvious.

HOME LIGHTING.*

BY GEORGE LELAND HUNTER.

Synopsis: The following paper presents some of the elementary considerations of residence or home lighting, particularly from the viewpoint of the interior decorator. The author regards home lighting as a decorative problem. He discusses in a general way the influence of colored surfaces and contrast upon the appearance and the decorative scheme of interiors. He suggests the co-operation of the architect, illuminating engineer and decorator to insure success and progress in lighting problems of this kind.

In the houses and apartments of New York and other large cities there are thousands of rooms gloomy and cheerless because they are not properly lighted, either by day or by night. Because of such rooms hundreds of flats and apartments are unrented which if properly illuminated could be quickly leased to responsible and permanent tenants.

The first impulse is to rush to the lighting fixture man or to the illuminating engineer, for assistance in solving the problem. From the name, people naturally assume that an illuminating engineer is one capable of producing ideal conditions of illumination in any kind of an interior. As a matter of fact the illuminating engineer has not always a remedy at hand to correct the bad lighting of dark rooms and apartments. Nor is the lighting fixture man any better off. They can talk about fixtures, candlepower, frosted bulbs and diffusing shades and the distribution of outlets, etc., but when assigned a problem in lighting a dark room agreeably and effectively they often fail. This is not their fault. The specialization of industry prevents most lighting fixture men from knowing anything about interior decoration and furnishings.

The problem of illuminating the interiors of houses and apartments is not only a fixture, but a decorative problem. Success in the future lies in the co-operation of architect, decorator and lighting fixture man. Of course when the architect really understands the art of interior decoration, as well as the planning and construction of buildings, his is the master mind that can best guide the lighting man and the decorator.

* A paper read before a meeting of the New York section of the Illuminating Engineering Society, December 12, 1912.

Illuminating a room means making clearly visible the form and color and texture of the objects in it. If the walls, furniture and other objects in a room are properly illuminated, then the room is illuminated. If they are not properly illuminated, then the room is not properly illuminated.

Of course there is opportunity for all kinds of contrast in lighting a room. Often the woodwork—the architectural background, the frame-work of the room—can be accentuated by being kept a little heavier in color and consequently darker than the flat surfaces of the walls. Often too the furniture is very properly accentuated in the same way. But if all the objects in a room, as well as the walls and ceiling and floor, are dark and somber, it is then impossible to illuminate the room at all.

The only thing that can be done is to distribute around the room a large number of light units having comparatively large shades of diffusing glass that will give large surfaces of brightness—but surfaces that are not too bright. With this wide distribution of light sources, wherever the eye turns it meets brightness, so that the effect is one of brightness. In illumination that is everything.

In measuring illumination, the photometer is practically useless. The human eye is the only capable judge. Whether a room is photometrically bright is of not the slightest importance. The only thing of importance is "Does the room look bright?" If it looks bright it is bright.

It is a well known fact that light surfaces reflect much light and that dark surfaces reflect little light. This means that the dark surfaces absorb the light, while the light surfaces reflect it. This applies, of course, not only to the walls of a room but also to the windows of a room. In illumination this fact is of vital importance. If the walls of a room are light, they not only look bright but they also reflect light to other walls, which re-reflect the light. And at each reflection but a small part, comparatively, of the light is lost.

I have noticed that many people in the evening leave the window shades up. Apparently it does not occur to them that every open window is a transparent hole through which the light leaks. And light costs money. Dark window shades also absorb

a great deal of light. Light shades not only reflect light in the room but by their brightness help give an appearance of brightness and cheerfulness to the whole interior.

While it is true that light surfaces always tend to recede from the eye and dark surfaces to advance toward the eye, it is also true that small spots or objects tend to stand out against a contrasting background. But bright objects against a dark background tend to stand out less than dark objects against a light background. These facts are of prime importance in the decorative and economical lighting of a room. The only way to light residences economically is to light them decoratively. If they are not lighted decoratively they are not lighted at all. It is lighting that makes a room agreeable and comfortable to live in.

The shape and size of rooms are also of vital importance in illuminating them. I find that a great many lighting fixture men do not seem to have any definite relation between the shape and size of rooms and the amount of light they provide. I will admit that the amount of light necessary varies very greatly according to the way the rooms are finished and furnished. A room finished and furnished in dark colors with surfaces of rough texture might require ten times as much light as a room with light smooth surfaces, and not be illuminated at that.

In my own practise, in rooms 9 feet high, I allow a 16 candlepower lamp for each fifty feet of floor space. In higher rooms I allow 10 per cent. additional light for each increase of one foot in height. This will be found too much light for light rooms, but too little for dark room.

There are some rooms in a house with ceilings too high for their size—such as narrow halls, bath rooms, etc. In these rooms ceiling reflection should not be utilized. The moment a ceiling is brightly lighted it appears to rise from one to two feet. Consequently in bath rooms and narrow halls the light should be kept off the ceiling, and placed upon the side walls, making the side walls appear to recede while the dark ceiling appears lower.

Of course, if a room is very wide and low, it is desirable to use ceiling reflection. By making the ceiling bright, its height is apparently increased; at the same time it may be used as a secondary distributor of the light.

Most of the talk about indirect illumination is nonsense. I would absolutely bar from use for ceiling fixtures anything that does not allow a fair proportion of the light to come down through the fixture. The best fixtures for what is called semi-indirect lighting are alabaster bowls and bowls of a similar kind of glass.

And now for the solution of the problem of lighting dark rooms in flats and apartments—lighting them by day as well as by night—even when the only window is on an air-shaft. The air-shaft should be light in color, white or ivory; then its walls will pick up and transmit the maximum of light from above and outside, provided there is a lateral opening. The only thing to do in lighting a room thus opening on an air-shaft is to make its walls and ceiling and furniture light in tone. Then in the daytime they will pick up from the air-shaft all the light there is and by reflection and re-reflection will give an appearance of cheerfulness and comfort to the interior.

One is often amazed to learn that while some owners of apartments have been fully instructed on this point they fail to act. The reason is as follows, as I learned by questioning several janitors. To finish the wood-work and doors of a small room in dark tones with cheap varnish costs about 75 cents and the varnish lasts on an average about three years; so that the real expense per room is only 25 cents. To finish the same room in white or ivory enamel costs $2.00 and the ivory enamel often needs renewing every year. Consequently the apartment owner balances $2.00 in one hand against 25 cents in the other, and says he will stick to the cheap varnish.

In decorative and economical lighting it is best to favor gold and yellows and oranges and greens of light tone, at the expense of reds and blues, particularly these in dark tones. Dark red and dark green or blue shades on lamps or fixtures simply kill the light. Especially effective in toning light for residence use are ground-glass shades of various shapes and sizes. These not only eliminate the burning effect of the light source, but they also cream the white slightly by eliminating some of the blue.

I dare say that by this time I have made it clear why I regard the problem of illuminating residences and apartments as a prob-

lem for the decorator and architect rather than for the illuminating engineer. But I want to say right here that unless the decorator and the architect take lessons from the illuminating engineer they will make terrible mistakes.

DISCUSSION.

MR. GEORGE S. BARROWS: Mr. Hunter's paper presents a part of the subject which many, who are qualified to solve the problems ordinarily presented, may find unfamiliar; and, therefore, for the best interest of the ultimate consumer, they should probably consult with some one familiar with that side of the question, which they have not studied in detail—the architect or decorator.

It is quite likely that neither the architect, the decorator nor the illuminating engineer would be quite satisfied with the solution of the problem solely by the other one, and therefore a compromise must be effected so that the result will be neither decorative alone on the one hand nor utilitarian alone on the other hand.

In one town where I am somewhat familiar with the method of operation of the illumination experts of a large gas company, the salesman endeavors to meet the architect and have him design the fixtures, suggesting, however, the number and the location of the outlets. The architect also indicates the design of the glassware and the general color of the light which he thinks should be used to best emphasize the details of the decoration. It is then up to the illumination expert to see that the proper burners, mantles and glassware are used, and if, in his opinion, the requirements of the architect will not give satisfactory results, a conference is arranged in order to discuss and eliminate the points of difference.

MR. G. B. NICHOLS: This subject is one of very vital interest to the Illuminating Engineering Society at the present time, for to obtain the highest efficiency in any system of illumination as planned for a new undertaking, there must be this co-operation of all concerned in designing the entire structure.

In general the owner holds off in making up his mind to build until the last moment or until the money needed has been entirely raised, and then he wishes building construction to start at once. This gives the architect but very little time to prepare his plans

so as to meet the owner's wishes or so that building construction can be started at the proper season of the year. After the architect has the plans well under way (in most cases about eighty to ninety per cent. completed) he, or the owner himself, will then engage specialists to co-operate in planning the different branches of engineering work required, such as illuminating, electrical, heating, ventilating, sanitary, etc. The architect is so rushed at this last stage of the work, that minor details such as color and character of finish of walls and illuminating fixtures are wholly deferred until after the building is well under way and more time can be given to their consideration. The illuminating engineer therefore must in most cases plan the outlets without knowing very much about the details of the rooms aside from general shape and use. Furthermore, the character of the illuminating fixtures is seldom considered at this time, the illuminating engineer being informed to provide enough outlets and sufficient wiring to take care of any system afterwards required.

A great deal of the trouble now causing poor illumination can be traced directly to the fixture houses who have not in the least tried to adapt their material and machinery to the present standards now being adopted, but rather force a great many of their antiquated and inefficient fixture designs to the front without any regard for illumination, or to the expense of upkeep of them.

In summing up it can truly be said that the architect needs the illuminating engineer to guide him in the selection of the appropriate illuminant; the illuminating engineer needs the architect's advice to design the proper standard or hanging for the illuminant and to approve the location and type of same so as to harmonize with the architectural design of the building, and at the same time the architect and the illuminating engineer need the skill of the decorator to blend the colors and wall decorations so as to add to the dignity and efficiency of the architect's design and the illuminating engineer's conception of light and shadows. The fixture manufacturer should also lend his aid in giving ideas in adapting the fixture design selected to the most economical method of manufacture so as to get the results both in respect to design and illumination at the lowest cost.

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Erratum.

The illustration at the bottom of page opposite page 106 of March, 1913 (Vol. VIII, No. 3) TRANSACTIONS has the words "light" and "dense" transposed. The globe on the left should have been designated as dense, and the one on the right light.

Council Notes.

The April meeting of the council was held on the 11th instant, in the general offices of the society, 29 West 39th Street, New York. Those in attendance were: Preston S. Millar, president; L. B. Marks, treasurer; C. J. Russell, George S. Barrows, W. J. Serrill, J. D. Israel, general secretary; V. R. Lansingh, Norman Macbeth, Alan Bright (representative of Mr. Howard S. Evans, vice-president of the Pittsburgh section) and James T. Maxwell and H. E. Ives by invitation.

A monthly report on the finances and membership of the society was received from the assistant secretary. According to the report of the current assets of the society, as of April 1, was $6,818; $4,313 of that amount represented cash in bank; the remaining $2,505 represented accounts owing to the society. The unpaid bills, April 1, amounted to $775. The net current assets as of that date, therefore, amounted to $6,043. The expenses for the first three months of 1913 was said to have aggregated $1,821. The membership, including the additions and the defections presented at the meeting, totaled 1,338 members. The membership at the beginning of the year was 1,335 members.

Vouchers Nos. 1241 to 1272, inclusive, aggregating $1,033.70, which had been approved and submitted by the finance committee, were authorized paid.

Mr. L. B. Marks, chairman of the committee on illumination primer, reported that the primer was to be translated into French by Professor A. Blondel of Paris and published within the near future. It was understood that the translation by Professor Blondel would not be published by any commercial organization. It was resolved that a set of the electros of the illustrations in the primer be sent gratis to Professor Blondel with the suggestion, that, if at any time they should be utilized for publication of the primer by any commercial organization, the society would desire to be reimbursed for their cost.

The executive committee was empowered to undertake preliminary negotiations looking toward a course of lectures on architecture and decoration with special reference to illumination.

A monthly report on activities of the

Philadelphia section was received from Mr. W. J. Serrill, vice-president.

A brief report on the work of the Chicago section was received from Vice-president Cravath.

President Millar announced a number of additional appointments to several committees. These were approved.

The officers of the society were empowered to appoint from time to time representatives in cities not having sections of the society.

The executive committee was empowered to act and fix a time and place for the 1913 convention of the society upon recommendation of the committee on time and place for the annual convention.

A list of members who were delinquent in the payment of their 1913 dues was read.

Section Notes.

CHICAGO SECTION

The April meeting of the Chicago section was postponed. Notices of the May meeting will be published shortly.

NEW ENGLAND SECTION

The New England section held a meeting in the auditorium of the Edison Building, Boston, April 21. Dr. Louis Bell presented a paper entitled "Notes on the Effect of Radiation on the Eye."

NEW YORK SECTION

At a meeting of the New York section in the United Engineering Societies' Building, April 9, Mr. M. Luckiesh of the National Electric Lamp Association, Cleveland, presented a paper entitled "Light and Art." The paper was supplemented by a series of demonstrations showing the effect of the direction, the quality and the distribution of light on various art objects. Mr. J. B. Taylor of the General Electric Company, Schenectady, N. Y., presented a paper on "Color Photography" which was also supplemented by a series of lantern slides and demonstrations. About 135 members and guests were present.

PHILADELPHIA SECTION

The Philadelphia section held a joint meeting with the Philadelphia Gas Works section of the National Commercial Gas Association and the Philadelphia Electric Company section of the National Electric Light Association, April 23, in the Parkway Building, Broad and Cherry Streets, April 23. Mr. T. W. Rolph of the Holophane Works of the General Electric Company read a paper on "Metal Reflectors for Industrial Lighting."

PITTSBURGH SECTION

At a meeting of the Pittsburgh section, April 18, in the Oliver Building, Mr. J. Frank Martin of the Duquesne Lighting Company presented a paper entitled "The Illumination of Motion Picture Projectors." The paper appears in this issue of the TRANSACTIONS. About 30 members were present.

A paper on "Train Lighting" by Mr. J. L. Minick of the engineering department of the Pennsylvania Railroad is scheduled for a meeting on May 9.

New Members.

The following twenty-four applicants were elected members of the society at a meeting of the council, April 11, 1913:

ASHLEY, EDWARD E., JR.
Consulting Engineer, Starrett & Van Vleck, 45 East 17th Street, New York, N. Y.

AUSTROM, CHARLES A.
Assistant Chief Engineer, The Travelers Insurance Co., Hartford, Conn.

BARROWS, ROBERT Y.
Chief Designer, The Mitchell Vance Company, 507 West 24th Street, New York, N. Y.

BURROWS, W. R.
General Electric Co., 5th & Sussex Streets, Harrison, N. J.

COLES, J. M.
Mgr. City Dept. and Engineer, General Gas Light Co., 80 Murray Street, New York, N. Y.

COX, EDWARD L.
Secretary, The Enos & Watkins Co., 36 West 37th Street, New York, N. Y.

DIBELIUS, ERNEST F.
The New York Edison Company, 124 West 42nd Street, New York, N. Y.

DESHON, F. B.
Deshon-Davidson Co., 323 Main Street, Tulsa, Okla.

DAWSEN, H. E.
General Electric Company, Harrison, N. J.

HARRINGTON, R. E.
General Electric Company, Harrison, N. J.

HEWLETT, ARTHUR T.
Hewlett-Basing Studio, 298 Fulton Street, Brooklyn, N. Y.

HIPPLE, W. C.
Superintendent, Westinghouse Lamp Co., 514 West 23rd Street, New York, N. Y.

INGRAHAM, EDGAR B.
General Electric Co., 30 Church Street, New York, N. Y.

KERR, THOMAS T.
The New York Edison Company, 124 West 42nd Street, New York, N. Y.

LEPAGE, CLIFFORD B.
Stevens Institute of Technology, Hoboken, N. J.

MULLEN, HOMER.
General Electric Company, Harrison, N. J.

ODAY, A. B.
General Electric Company, Harrison, N. J.

PECK, ROBERT C.
Electrical Testing Laboratories, 80th Street & East End Avenue, New York, N. Y.

PERRY, J. W.
General Manager, H. W. Johns-Manville Company, Madison Avenue & 41st Street, New York, N. Y.

SHAKIN, VICTOR.
Electrical Testing Laboratories, 80th Street & East End Avenue, New York, N. Y.

SUMMERS, JOHN A.
General Electric Company, Harrison, N. J.

THISTLEWHITE, R.
New York Electrical School, 39 West 17th Street, New York, N. Y.

WARNER, J. PAUL.
Iron City Engineering Co., 1172 Frick Annex Bldg., Pittsburgh, Pa.

WYATT, CHAS. K.
Salesman, H. W. Johns-Manville Company, Madison Avenue & 41st Street, New York, N. Y.

Sustaining Members.

At a meeting of the council, April 11, 1913, the following companies were elected sustaining members of the society:

Consolidated Gas Company of Boston.
The Benjamin Electric Company.
The Commonwealth Edison Company of Chicago.
The Edison Electric Illuminating Co. of Brooklyn.
National Electric Lamp Association.
The Macbeth-Evans Glass Company.
Westinghouse Lamp Company.

German I. E. S.

The first general meeting of the German Illuminating Engineering Society was held on the 25th of February in the large auditorium of the Physical Institute of the University of Berlin.

The meeting was called to order by the chairman of the temporary council, Dr. E. Warburg, president of the Physikalisch-technische Reichsanstalt. In his address President Warburg stated that the chief aim of the society was to attain agreement regarding the light unit, regarding nomenclature and regarding methods of measurement, and to establish standards. He emphasized very strongly the necessity for international agreement in these matters and pointed out the great significance of such agreements for the development of science and industry. He pointed out the function of the society in uniting and bringing into harmony, theory and practice as regards illumination, and stated that on account of these important factors, the Physikalisch-technische Reichsanstalt had done its utmost to further the formation of the society. Especially interesting was a statement that at the Reichsanstalt, experiments are in progress from which they have great expectations of realizing a primary standard of light which will receive international sanction. This is founded on the use of the black body as a radiator, held at a definite temperature.

The secretary, Dr. E. Liebenthal, reported that 51 had taken part in the meeting for organization in November and that now the number of members had grown to 211. The committee on permanent officers reported, and the following were elected: president, Prof. Dr. E. Warburg; vice-president, Geheimrat Lummer; vice-president, Geheimrat Harber; secretary, Prof. Liebenthal; secretary, Dr. Krüss; treasurer, Direktor Schaller; president of the council, Geh. Ober-Postrat Dr. Strecker; chairman of committee on light unit, Geh. Rat Hagen; chairman of committee on nomenclature, Dr. Strecker; chairman of committee on methods of measurement, Geh. Rat Brodhun.

—Translated from Zeitschrift für Beleuchtungswesen by C. H. Sharp.

Glare from Reflecting Surfaces.

The committee on glare from reflecting surfaces is preparing an eight-page pamphlet which will bring to the attention of the reader the necessity of eliminating glare from glazed paper, polished or glass desk tops, glazed blackboards and walls. Two leaves of the pamphlet will be of highly calendered stock, while the two remaining leaves will be of unglazed book paper. It is hoped that this pamphlet will impress upon each reader the importance of eliminating from general use all polished surfaces and especially glazed paper. As paper is the most common source of glare with which the committee is concerned, data are constantly being collected on printing processes and available matt-surface papers. This enables the committee to co-operate with publishers who desire to enlist in the army of vision conservationists.

Factory Lighting Legislation.

Quoted below is a section of Bill No. 26 of the laws of the State of New York entitled "An Act to amend the labor law, in relation to the protection of employees operating machinery, dust creating machinery, and the lighting of factories and workrooms."

This section of the bill, which relates particularly to lighting of factories, passageways and workrooms, was drafted in accordance with recommendations made by the committee on factory lighting legislation of the Illuminating Engineering Society. The bill was signed by Governor Sulzer April 17, 1913.

All passageways and other portions of a factory, and all moving parts of machinery which are not so guarded as to prevent accidents, where, on or about which persons work or pass or may have to work or pass in emergencies, shall be kept properly and sufficiently lighted during working hours. The halls and stairs leading to the workrooms shall be properly and adequately lighted, and a proper and adequate light shall be kept burning by the owner or lessee in the public hallways near the stairs, upon the entrance door and upon the other floors on every work day in the year, from the time when the building is open for use in the morning until the time it is closed in the evening, except at times when the influx of natural light shall make artificial light unnecessary. Such lights shall be so arranged as to insure their reliable operation when through accident or other cause the regular factory lighting is extinguished.

All workrooms shall be properly and adequately lighted during working hours. Artificial illuminants in every workroom shall be installed, arranged and used so that the light furnished will at all times be sufficient and adequate for work carried on therein, and so as to prevent unnecessary strain on the vision or glare in the eyes of the workers. The industrial board may make rules and regulations to provide for adequate and sufficient natural and artificial lighting facilities in all factories.

This act shall take effect October first, nineteen hundred and thirteen.

TRANSACTIONS

OF THE

Illuminating Engineering Society

APRIL, 1913

PART II

Papers, Discussions and Reports

[APRIL, 1913]

CONTENTS -- PART II

A PHOTOMETER SCREEN FOR USE IN TESTS OF STREET ILLUMINATION.

BY ARTHUR H. FORD.

Synopsis: This paper puts forth the proposal that in illumination measurements a test-plate with rounded surfaces or one with several plane surfaces, the mean illumination of which has been determined, be used in place of the usual flat translucent photometer test-plate. It gives comparative illumination readings obtained with the use of five different test-plates.

The purpose of street illumination being the making visible of obstructions to traffic, which obstructions seldom have plane surfaces making definite angles with the street surface, the ordinary method of measuring street illumination on a horizontal plane or one normal to the ray of light does not give the information desired. The writer proposes to overcome this defect by using, as a screen, a body with rounded surfaces or several plane surfaces; the mean illumination of which is determined. Such a screen would correspond to a brick if plane surfaces were used or a stone if rounded surfaces were used; and the illumination would be, to a considerable extent, independent of the direction from which the light comes.

This paper is the record of some tests with screens having various configurations.

Since the surroundings of the photometer cannot be controlled in street photometry as in laboratory work, it is obvious that the surfaces used must be those of a translucent body attached to the viewing part of the photometer. The screens tested were mounted, in turn, on the elbow tube of a Sharp-Millar photometer and readings of the instrument made as the angular position of the test lamp was changed through 90 deg. Polar curves were then plotted between the angular position of the test lamp and readings of the photometer, in terms of the maximum reading obtained with the particular screen being tested.

The following screens were used:

No. 1.—A plate of translucent, milk white glass with a ground surface (Fig. 1), the glass being the regular diffusing screen furnished with the photometer.

No. 2.—A cube of paraffin 1⅝ inch (4.1 cm.) on a side; one side covered with an opaque screen (Fig. 2). While paraffin is not a suitable substance for making permanent screens, the ease of moulding it into irregular shapes adapts it admirably for making screens for temporary use. Its optical properties are satisfactory if the screens are carefully selected for uniformity of texture and optical symmetry.

No. 3.—One quarter of a paraffin sphere 1⅝ inch (4.1 cm.) in radius having one flat side covered with an opaque screen (Fig. 3).

No. 4.—An "Alba" glass hemisphere 3 inches (7.6 cm.) in diameter having one half blackened Fig. 4). This globe is about ⅛ inch (0.3 cm.) thick; the translucence being due to air bubbles in the glass.

No. 4a.—The same screen as No. 4, but with the addition of a piece of paper on the flat side of the hemisphere.

The following data were obtained:

SCREEN NO. 1.

Angle of lamp.	Photometer reading.
90	100
80	97
70	90
60	81
50	70
40	60
30	46
20	34
10	—
0	—

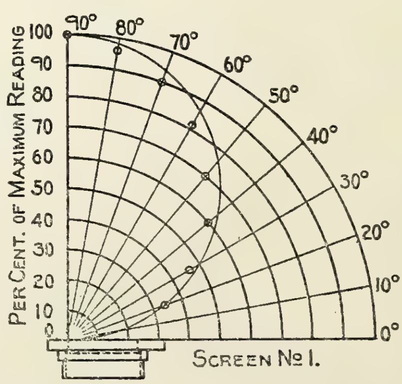


Fig. 1.

SCREEN No. 2.

Angle of lamp.	Photometer reading.
90	57
80	65
70	81
60	85
50	100
40	100
30	95
20	96
10	99
0	75

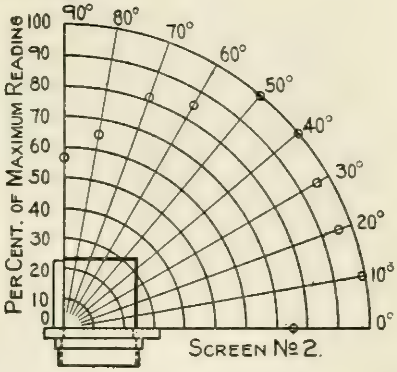


Fig. 2.

SCREEN No. 3.

Angle of lamp.	Photometer reading.
90	75
80	87
70	94
60	97
50	100
40	100
30	93
20	91
10	84
0	66

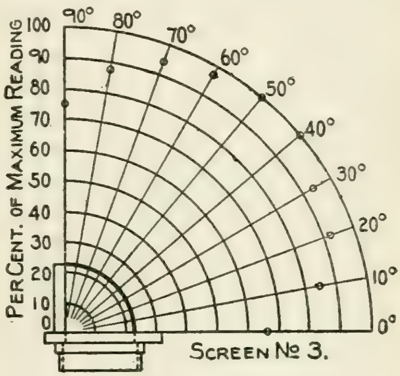


Fig. 3.

SCREEN No. 4.

Angle of lamp.	Photometer reading.
90	100
80	70
70	52
60	46
50	42
40	37
30	35
20	33
10	28
0	22

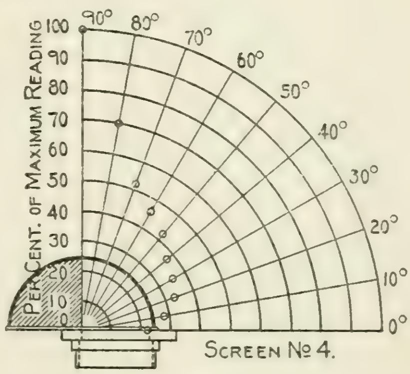


Fig. 4.

SCREEN NO. 4a.

Angle of lamp.	Photometer reading.
90	70
80	82
70	92
60	100
50	100
40	97
30	91
20	87
10	72
0	61

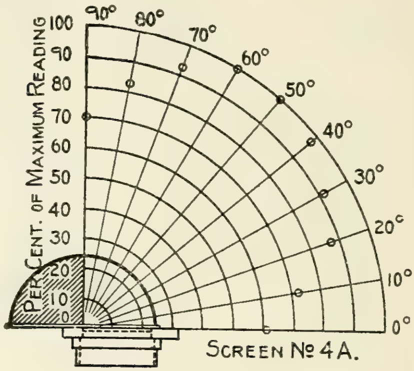


Fig. 4a.

CONCLUSION.

Screens Nos. 3 and 4a are satisfactory for use in street photometry, with the advantage somewhat in favor of No. 3 because of the small dependence of illumination determinations on the direction of the light source. The writer would suggest the use of a screen of this form made of "Alba" or some similar glass.

DISCUSSION.

DR. C. H. SHARP (communicated): Prof. Ford makes the statement that the ordinary method of measuring street illumination on a horizontal plane or on one normal to the ray of light, does not give all the information requisite to determine the visibility of objects on the surface of the street. This is quite true. He proposes to overcome this difficulty by using a test screen which gives a value which represents an indeterminate mixture of illumination values in various planes. It is not at all clear that this represents a solution of the difficulty.

In the first place, it must be noted, as Millar has pointed out, that objects on the street are seen because of a difference of the brightness of the object and its background. A brick lying on the street may be seen because it is whiter than the street surface; or because to the observer a vertical surface of the brick is brighter than the horizontal surface of the pavement, a condition which may be due either to the brick being actually whiter or to the

illumination on the vertical plane being greater than that on the horizontal plane; or it may be seen because a vertical surface of the brick is darker than the street surface, which may be because it lies in its own shadow. There are then various conditions which determine visibility and which arise from the relations between the object viewed, the lamps illuminating it, and the relative reflecting power of the object and of the street surface, as well as upon the illumination in various planes. Therefore, even if we know all there is to be known about the illumination in all the various planes conceivable, we could not say that any brick would be visible from any point unless we had some other items of information besides. Illumination values alone would not tell us. Therefore at best Prof. Ford's solution is an imperfect one.

From a scientific point of view also his proposition seems to be untenable. When we consider the illumination at a certain point on a certain plane, we are dealing with a perfectly definite physical quantity. The only arbitrary question is how perfectly the test plate used in making the measurement of that illumination conforms to the ideal law of diffusion. When, however, we measure the brightness of a certain piece of paraffine or a certain hemisphere of a certain kind of glass, we have a result which is purely arbitrary and incapable of interpretation in simple terms. It is also very questionable whether hemispheres of diffusing glass could under the best conditions be made so like each other that they would always show the same diffusion characteristics. Unless it were possible to reproduce these hemispheres, it would be impossible to make all illumination photometers give the same results under the same conditions. And there is no reason to suppose that in the present state of the art of glass making, this can be done.

It would be interesting if Prof. Ford were to study the illumination on a street using his proposed test plate, and were then to present a paper to the society telling just what that illumination was in actual physical units.

Mr. M. Luckiesh (communicated): Prof. Ford presents some interesting data regarding the problem of measuring "illuminating efficiency." It is true that street lighting presents some distinct problems in the matter of rating illumination

according to its ability to make objects visible but interior lighting is not free from the same problems. Various methods for measuring "illuminating efficiency" have been suggested but the one used at present, although deficient, will no doubt be adhered to until illuminating engineers agree on the answer to the question. How does the direction of the incident light affect the ability of that light to make objects visible?

This question will not be answered without fully analyzing illumination. With this in mind the writer has studied in detail the distribution of natural and artificial light in interiors. This work which appeared in the TRANSACTIONS for October, 1912, is only a beginning of the analysis which must be made in order to conclude just how lumens incident from various directions should be weighted.

Prof. Ford's screens, Nos. 3 and 4a, which he considers satisfactory for use in street photometry take into account light incident within an angular range of 90 deg. (considering only the vertical plane parallel to the direction of the street). Obviously the screen or the whole photometer must be rotated 180 deg. in order to account for the light from the other light source because there would be positions where sources on opposite sides of the photometer would contribute light. Just how he would weight these two measurements is not stated.

To fully emphasize the complexity of the problem, consider a case where one sees a vehicle in silhouette against a bright background such as a highly illuminated pavement. In such cases visibility depends upon the contrast of the dark background; therefore the less light that is incident on the vehicle from the general direction of the observer the more visible will the object be.

These points are cited merely to emphasize the fact that more work must be done on the analysis of illumination. In view of the lack of agreement regarding the method of determining "illuminating efficiency" the writer cannot wholly agree with Prof. Ford's conclusion that screens Nos. 3 and 4a are satisfactory for street illumination. It would be interesting to learn why he reached this conclusion. Prof. Ford's data are very interesting and certain of those screens may perhaps find immediate

application in special cases. However, the data will be of greater use after illuminating engineers reach an agreement and decide what they desire to measure.

Mr. G. H. Stickney (communicated): The failure of the normal intensity or that on a horizontal surface to express the true values of street illumination has long been evident and not infrequently has been the subject of discussion among illuminating engineers. While I believe it is generally conceded that the true values lie somewhere between those determined by the above mentioned methods, there seems to be no general agreement as to just where these values fall, and it is quite probable that, under different conditions, their relative position between these two extremes may vary.

About 1906 Mr. W. D'A. Ryan and myself experimented a little with a translucent hemisphere and also with other spherical sections partially blackened or coated with tin foil, but, on account of various difficulties, did not arrive at a form of screen which we were willing to recommend.

Beyond the difficulty of determining the intermediate values which would be acceptable as fair to both large and small units with wide and narrow spacing, we were unable to secure a screen which would make accurate measurements on very low intensities. It will be remembered, in this connection, that the class of problems where this type of measurement is important are those in which the actual normal intensities may run as low as 1/100 foot-candle or less. While we obtained accurate settings with diffusing screens of opal glass and paraffine with values above one foot-candle, we did not have much success with low intensities; that is, 1/10 foot-candle or less.

In looking over the curves presented by the author I would agree that screens No. 3 and 4-a show a better characteristic curve than the other forms. Still I believe that many observers will feel that both of these types give too much weight to light in angles approximating zero degrees.

While at present the difficulties seem almost unsurmountable, it must be recognized that there is an insistent demand for a better method of determining the value of street lighting intensities and any work tending toward this end will be of great value.

THE FLAME CARBON ARC LAMP.*

BY W. A. DARRAH.

Synopsis: The operating characteristics of the recently developed flame carbon arc lamp upon direct and upon alternating current supply are outlined and illustrated in the following paper. Flame carbons and their light giving properties and characteristics are also discussed. The author states that this lamp is peculiarly well adapted to street and large area lighting on account of the color (which approximates a daylight value when white flame carbons are used) and distribution of its illumination, and on account of its comparatively low operating and maintenance costs. The efficiency of this type of lamp (with white flame carbons) quoted in mean lower hemispherical candles per watt is said to vary from 2.5 with light opal globes to 5 with clear glass globes; yellow carbons, the author adds, may be obtained which will give from 30 to 50 per cent. more light for the same energy consumption.

The methods of lighting to-day are being revolutionized. Hundreds of thousands of dollars worth of old equipment, is yearly being sent to the scrap pile, to be replaced by more efficient, more effective, more economical apparatus. The number of "great white ways" is being multiplied monthly. Civic bodies and merchant's associations are clamoring for more light.

One of the fundamental causes of the transition now in progress, is the rapid, and very complete development and commercialization of the long-burning, flame carbon arc lamp. The flame carbon arc lamp is not new. It does not even in its present highly developed form, depend for its operation upon new theories, or recent discoveries. But it does depend for its present swift and complete development upon the awakening of civic pride, the discovery of the enormous commercial value of light, and the accompanying prosperity which has swept across the country.

The subject of long burning flame carbon arc lamps is too large a one to be treated in a limited paper of this kind. It is proposed here to very briefly touch on some characteristics of long burning flame carbon arc lamps, to show how these characteristics particularly adapt this illuminant for some fields of work, and to then

* A paper read before a meeting of the New England section of the Illuminating Engineering Society, February 17, 1913.

consider some points in connection with the design of these lamps from the standpoint of the operating man.

The long burning flame carbon arc lamp, is to-day, without doubt, the most efficient, commercial source of light considering at the same time color value; and what is unfortunately not always true of illuminants of this class, it is also the most economical to operate, considering the average conditions of cost of energy, labor, and materials when the mean lower hemispherical candle-power required exceeds five or six hundred.

The light of the flame carbon lamp is steady and the distribution excellent for lighting large areas with considerable uniformity. The color may be varied within a rather wide range from white to yellow depending upon the kind of carbons employed. Other colors such as red, blue, green, etc., may of course be obtained if sufficient demand for them should arise, as, for instance, for advertising purposes or where special colors lend themselves more readily for special work.

A further highly desirable attribute of the flame arc, and one which has perhaps not yet been fully appreciated is the reduced intrinsic brilliancy over the carbon arc, due to the relatively large area of the light source. While the intensity of the flame arc is so great that even with the much larger area of the light source it is usually desirable to use diffusing glassware, yet the shadows are far softer and the distribution more uniform than can be obtained with the older forms of arcs.

CHARACTERISTICS OF THE FLAME CARBON ARC.

A consideration of the flame carbon arc is only of value in connection with a lamp and a specific variety of carbons. In the statements which follow an enclosed flame carbon arc lamp similar to that shown in Fig. 1 is considered, although the discussion in general applies to other lamps of this type. The carbons under consideration are assumed to be commercial carbons, varying in diameter from 5/8 in. to 7/8 in.

In appearance, the flame carbon arc more nearly resembles the metallic flame arc than any other type. It consists of a long ill-defined flame which is intensely luminous and is terminated with a bright point at each end. Both the alternating and direct cur-

rent arcs have these characteristics, and it is very difficult to distinguish the direct current from the alternating current arc by inspection. No crater is formed on the positive carbon and the distinct cathode spot on the negative carbon is less conspicuous. It is probable that the length and density of the arc material prevents the scouring action of the particles emitted by the arc, which probably cause the crater in the case of the open direct current arc. Unlike the enclosed carbon arc, the flame is intensely luminous and is the source of a considerable amount of radiation in the red and green portions of the spectrum.

The majority of light comes from the luminous flame, although the terminals of the arc have a higher intrinsic brilliancy than the other portions.

The arc may have any color, depending upon the materials used in the carbons. Commercially, white and yellow light carbons are mainly employed, although under special conditions, for special purposes, other colors are occasionally used. The color of the arc is dependent upon the current density to some extent. In other words, an arc that would be white with certain values of current density, may become distinctly yellow when the current density is materially decreased. It appears that the temperature of the arc also has considerable effect upon the color, since an arc which will burn white under normal conditions, may become intensely yellow when the temperature is lowered, either by cooling the terminals, by special air draft, or by forming the arc in an atmosphere which will readily conduct the heat away. It seems probable that the change in color may be produced by lowering the temperature of the minute particles which are luminous, to a yellow heat instead of allowing them to remain at a temperature sufficiently high for the radiation of white light.

It is interesting to note that the addition of water vapor to the arc chamber will cause an arc normally emitting a white light to burn yellow. A further suggestive fact is that certain gases may be present in the arc chamber which will cause a yellow arc to become intensely white.

Fig. 2 shows an alternating current flame carbon arc between ⅞ in. carbons and an atmosphere of carbon monoxid and nitrogen. This was a 10-ampere arc with a potential between the electrodes

Fig. 1.—Enclosed flame carbon arc lamp.

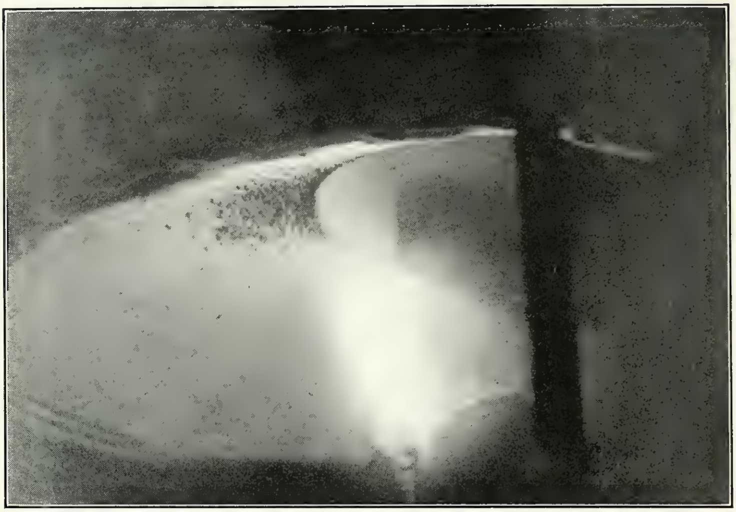


Fig. 2.—A 10-ampere, 50-volt alternating current flame carbon arc between ⅞ in. carbon and an atmosphere of carbon monoxid and nitrogen. The magnetic blow away from the side rod is clearly shown.

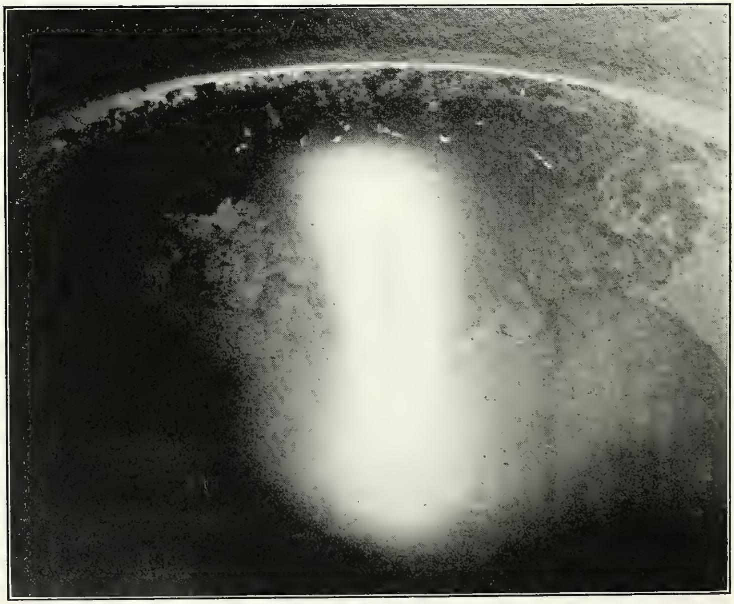


Fig. 3.—A 6.5-ampere, 70-volt direct current flame arc between ⅞ in. carbons under normal conditions.

of approximately 50 volts. In this arc, the magnetic blow away from the side rod may be distinctly noted.

Figs. 3 and 4 show direct current, 6.5-ampere, 70-volt arcs between ⅞ in. carbons. It will be noted that both ends of the direct current arc are distinctly luminous and very similar in appearance to the alternating arc. Fig. 3 shows the arc under normal conditions, while Fig. 4 shows the so-called non-magnetic arc which is considerably diffused and very slightly affected by a magnetic field. Figs. 5 and 6 illustrate an enclosed carbon arc between unimpregnated ½ in. carbons operating under similar conditions to the flame carbon arc. It will be noted here that the electrodes of the enclosed carbon arc are intensely bright. Since the arc between the unimpregnated carbons emits a large percentage of blue and ultra-violet rays, the photograph shows this arc considerably more luminous than it appears to the eye.

The diameter of the flame carbon arc under normal conditions is approximately ⅜ in. Curve 1, of Fig. 7, shows the length of the flame carbon arc with various voltages applied to the terminals and with constant current. It will be noted that the length of the arc ranges from ½ in. with 40 volts, to approximately 5 in. with 220 volts. The increase is substantially a straight line. If continued, the curve would pass through the zero separation point with about 30 volts drop, indicating that this is the loss at the terminals independent of the length of the arc. Calculated on this basis, an arc 5 in. in length and having a total drop of 220 volts would have 190 volts loss throughout its length, or a drop of 38 volts per inch. This is equivalent to about 3.8 ohms per inch of length for a 10-ampere, direct current arc, which while somewhat higher, is not very materially different from the conditions often obtained in the enclosed carbon arc.

Curve 2, on Fig. 7, is the well-known characteristic curve of an arc. It will be noted that when the current exceeds approximately 6.5 amperes, the flame carbon arc becomes exceedingly stable. In other words, the drop in voltage across the arc increases in approximately the same ratio that the current is increased. This is somewhat different from the titanium and enclosed arcs which are correspondingly very much more unstable. The causes of the stability of the flame carbon arc on

currents above 6.5 amperes are mainly two: first, the relatively high resistance of the arc and the increase of this resistance as the length increases; and, second, the lower evaporation point and greater volume of the materials in the flame carbon arc. In this connection, it is interesting to note that these two conditions, together with the higher margin between the temperature at which the arc is a conductor and the tempearture at which it is not, allow of the satisfactory operation of the flame carbon arc upon circuits, the frequencies of which is as low as 25 cycles.

Figs. 8, 9 and 10 respectively, show oscillograms of the titanium arc, the enclosed carbon arc and the flame carbon arc. It will be noted that while the current wave has substantially the same distortion in the case of the titanium and enclosed carbon arcs, it is very much more nearly a sine wave in the case of the flame arc. An inspection of the oscillographs shows that the distortion of the voltage wave is very considerably greater than the distortion of the current wave. The titanium arc shows a distinct peak at the instant at which the current is interrupted and a very steep wave front. This distortion of the current and voltage wave in the titanium arc is so great and their centers are displaced to such a degree that the resultant power factor is approximately 50 per cent.

The distortion of the enclosed carbon arc is somewhat less, but the displacement of the current and voltage waves is sufficient to reduce the power factor to approximately 80 per cent. It is interesting to note the higher harmonics which are present in the voltage wave of the enclosed carbon arc are absent in both of the flame arcs.

The voltage wave of the flame carbon arc shows less distortion than either of the other arcs, and the displacement is so slight that the power factor ranges from 85 to 90 per cent. The above discussion should be understood to apply entirely to the power factor of the arc itself and to be independent of the lamp mechanism or coils.

The advantages of the higher power factor are well known, while the advantages of the smoother wave form are: lower voltage strains, more stable arcs, and less induction between arc circuits and adjacent telephone or telegraph circuits.

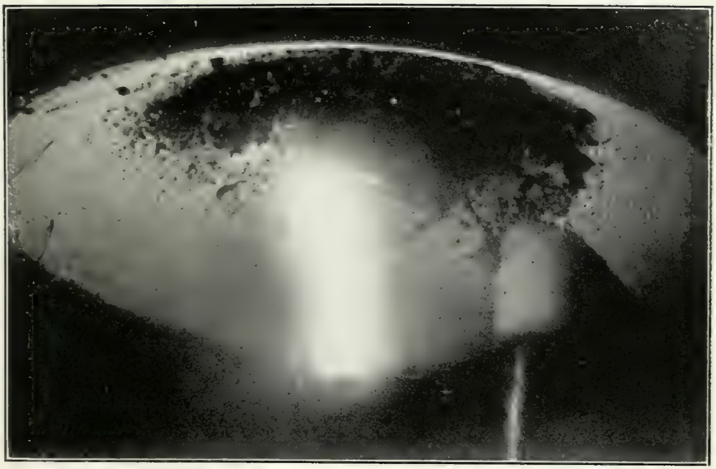


Fig. 4.—A 6.5 ampere 70-volt direct current flame arc between ⅞ in. carbons. The so-called non-magnetic arc which is said to be only slightly affected by a magnetic field, and considerably diffused, is plainly illustrated.

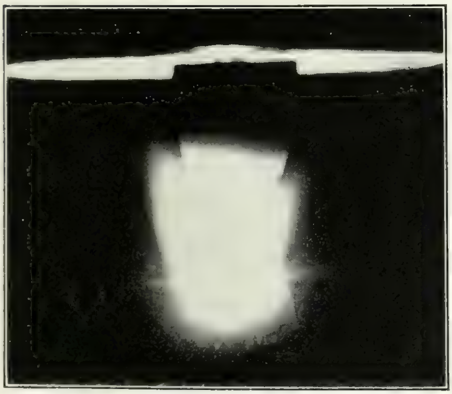


Fig. 5.—An enclosed carbon arc between ½ inch unimpregnated carbons.

Fig. 6.—An enclosed carbon arc.

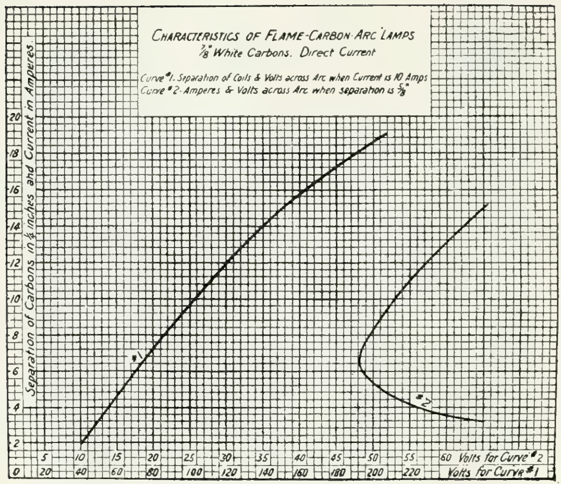


Fig. 7.—Characteristics of flame carbon arc lamps.

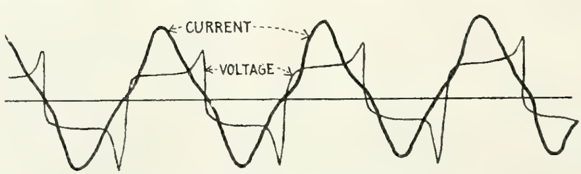


Fig. 8.—Oscillograms of titanium arc.

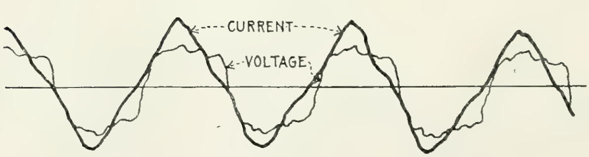


Fig. 9.—Oscillograms of enclosed carbon arc.

As previously pointed out, the smaller distortion and higher power factor of the flame carbon arc results largely from the sloping characteristic curve which is due to the greater margin between the temperature at which the gases of the arc conduct and the temperature at which they do not, to the greater volume of volatile material in the arc and the lower vaporization point of this material.

The flame carbon arc is inherently a large energy light unit. Since the light is emitted quite largely by the flame, it is desirable to have the flame as long as possible. Since the drop at the electrodes is fixed at approximately 30 volts and since the resistance drop of the flame is approximately 38 volts per inch (for a 10 ampere arc) it will be evident that a comparatively high

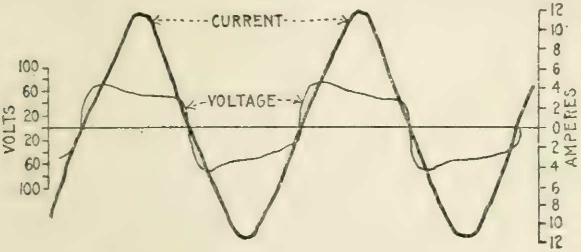


Fig. 10.—Oscillograms of a flame carbon arc.

voltage is desirable for most economical operation. This statement, together with all other statements regarding the operating characteristics of the arc, should be considered as applying to the commercial type of carbons at present on the market, and it should be kept in mind that it is possible to materially vary these operating characteristics by employing special types of carbons.

The present current densities which have been found most satisfactory are as follows:

	Per square inch. 100 amps.
(1) Current density at the arc	100
(2) Current density at the arc, negative terminal, approximately	1,500
(3) Current density at the arc, positive terminal, with diffused arc	35

With commercial carbons, best results are secured with approx-

imately 10 amperes through the arc and it is upon this basis that the above statements are made. Since the power factor of the flame carbon arc is approximately 85 per cent., it will be evident that the wattage under which most satisfactory operation may be obtained lies between 350 and 500 watts, more economical operation being obtained with a higher wattage.

CONSIDERATION OF FLAME CARBONS.

As the carbons mark one of the greatest differences between the present flame carbon arc lamps and the old solid carbon arc lamps, some space may properly be devoted to their consideration.

The flame carbon differs from the solid carbon in that certain chemicals are added during their manufacture with the object of increasing the light; securing better operation, and reducing slag troubles. The chemicals commonly added may be classified as follows:

(1) *Illuminants.*—These comprise the compounds of three or four peculiar elements. For white light, cerium and titanium offer the greatest possibilities; while calcium and, to some extent, tungsten form the main illuminants in yellow light carbons.

(2) *Sustainers.*—Since the flame carbon arc, as illustrated in Figs. 2, 3 and 4 is very considerably longer than the enclosed carbon arc, it would be prohibitively unstable unless certain compounds were added to remedy this defect. At present, fluorides and to a small extent, borates, form the most suitable sustainers when slag troubles, evaporation point and cost are considered. These elements are frequently introduced as compounds of the illuminants.

(3) *Conductors.*—In order to overcome certain troubles which arise due to slag which may form in case the carbon is consumed more rapidly than the illuminants and sustainers, certain compounds are frequently added to prevent slag troubles which might otherwise result.

By a series of long experiments—for theory does not seem to be at present sufficiently developed to do much more than indicate the direction of progress—the large carbon manufacturers have to-day developed flame carbons which are entirely commercial and which give excellent results, both from the standpoint of efficiency and operation.

In view of the scarcity of consistent data, it is perhaps, dangerous to venture a theory to account for the high efficiency of the flame carbon arc. One explanation, however, which seems reasonable and which accounts for a large number of facts which have been observed, is to consider the arc as a place where the mineral compounds with which the carbons are impregnated are raised to such a temperature that dissociation is continually in progress and that at very short distances from these points of high temperature, re-combination is occurring very vigorously. In this process of dissociation and re-combination, the elements which form the illuminants become raised to the temperature necessary for selective radiation.

A consideration of the position in Mendeleff's table of the elements which form the illuminants of the arc, and of the chemical characteristics of these elements, makes the above theory appear more probable. In addition to the high temperature necessary to allow selective radiation, it is essential that the illuminant be composed of a material which readily forms compounds having a very high melting point and vaporization point. All of these requirements seem to be met by the oxides of cerium, calcium and tungsten. In this connection—as previously pointed out—the effect of cooling the arc and thereby changing its color from white to yellow is very suggestive.

Fig. 10a shows the variation of candle-power which occurs with increased voltage on a 10-ampere, alternating current flame carbon arc between various varieties of carbons. These curves are interesting as indicating that, with few exceptions, the candle-power increases directly with the voltage until a certain value is reached, and in some cases somewhat more rapidly. This is to be expected, as the increased voltage allows an increased arc length and therefore a longer flame. When a certain value of voltage and a certain arc length has been exceeded, additional cooling effects introduced prevent a material increase in the total light flux emitted, and for this reason, the curve flattens out after passing a certain critical point.

Fig. 11 shows the effect of increased currents on a 48-volt, 60-cycle arc under normal conditions. It will be noted that the light emitted increase uniformly with the current over the majority of

the range given. Depending upon the amount of illuminants in the current increases. This affords a rough means of determining the amount of illuminant in a given grade of carbons. In this connection, it is interesting to note that the addition of illuminants to a flame carbon does not increase the total light emitted in a direct ratio to the amount of illuminants added. In other words, as the percentage of cerium oxid in a white-light carbon is increased, the candle-power first increases until a maximum value

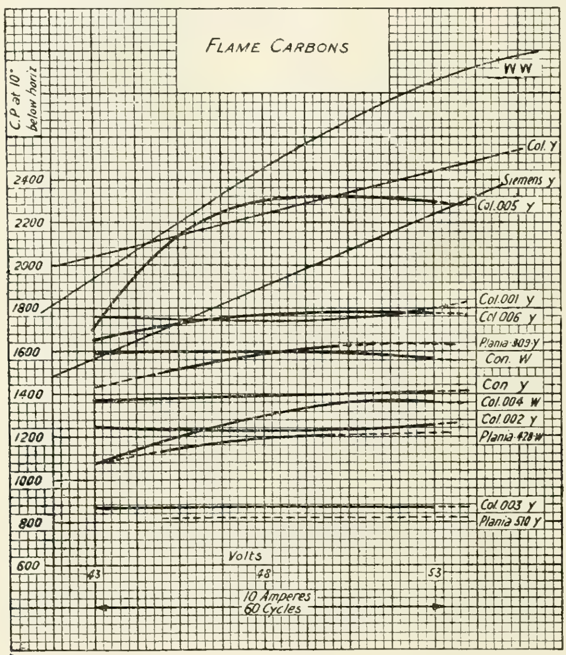


Fig. 10a.—Variation in candle-power with increase of voltage across arc of flame carbons.

is reached, after which the addition of more cerium oxid will decrease the intensity of the light emitted for a given amount of electrical energy. This condition together with the effect of slag, which may be very serious in improperly designed carbons, limits the amount of mineral material which may be added to the carbons.

The difficulties introduced by slagging of the flame carbons has

received considerable attention and has been overcome commercially. Assuming that these carbons are properly designed, the outage during normal, commercial operating conditions should not exceed ½ to ¾ of 1 per cent., provided the lamps are maintained in the proper condition.

Slagging may be caused by the entrance of air into the arc chamber, due to imperfect globe seats or leaking condensers. The excess of air causes the consumption of the carbons to proceed more rapidly than the mineral components can be vaporized.

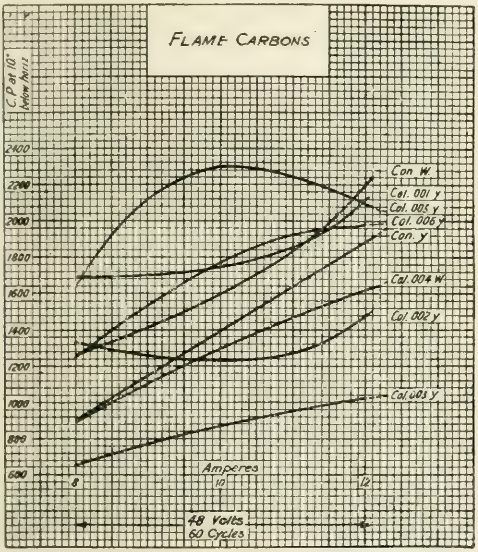


Fig. 11.—Variation of candle-power with increase of current of arc with flame carbons.

This allows an accumulation of fused oxids and fluorids upon the surfaces of the electrodes, thus forming when cold, an insulating layer. An excessively low current or an arc longer than normal may also cause slagging.

None of the difficulties mentioned above should be encountered in the commercial lamps providing proper globes are used and the lamps are maintained in good condition. A very small amount of slag is no detriment to the operation of the flame carbon lamp

since the hammer blow which is given when the carbons fall together prevents trouble of this nature from being serious.

From a mechanical standpoint, it may be stated that the carbons now commercially obtainable are entirely satisfactory. Present diameters vary from approximately ¾ in. to ⅞ in., depending upon the conditions under which they are used. It is possible to secure these carbons within 0.025 in. from the specified diameter without adding appreciably to their cost. Since this is true, it will be evident that a ring clutch may be employed in the operation of flame carbon lamps with entire satisfaction.

Since the average flame carbon contains more than 30 per cent. of solid material which is not consumed, but which must be vaporized by the arc, the problem of disposing of this material naturally required solution. It was found that this solid material (called "soot" by lamp operators) would not condense upon surfaces which were maintaind at an elevated temperature, while it will readily condense in the form of a soft white powder upon any cool or relatively cool surface. This is taken advantage of by so arranging the globes of the lamps that they will be materially hotter than a second and communicating chamber into which the gases from the arc are forced.

The second chamber, which is made of metal and designed to expose a comparatively large surface to the air, is called the "condensing chamber" (Fig. 12), shows an outline sketch of a flame carbon lamp and indicates the path of the gases from the arc. It will be noted that this lamp is so designed that the majority of the gases which carry the vaporized mineral material pass directly into the condensing chamber where the majority of the soot is deposited. The condensing chamber also contains sticks of magnesia or other alkaline material which will readily combine with the hydrofluoric acid, nitric acid, etc., preventing the free acids from attacking the globe, thereby decreasing its transparency and the amount of light emitted.

An examination of the arc through an absorbent glass shows a very rapid movement of the gases immediately surrounding the arc. Streams of semi-luminous vapors may be noted being projected violently upward from the arc flame. These vapors con-

tain the so-called "soot," together with hydrofluoric, nitric and sulphuric acids.

Since the temperature of the arc in its cooler portions probably exceeds 2,500 deg. C., while the remainder of the arc chamber is filled with gas at a temperature not exceeding 150 deg. C., it is obvious that the different density of the two gases is sufficient to account for the violent motion in the vicinity of the arc.

In connection with the wash of air from the arc around the upper carbon is found an explanation of the markedly different

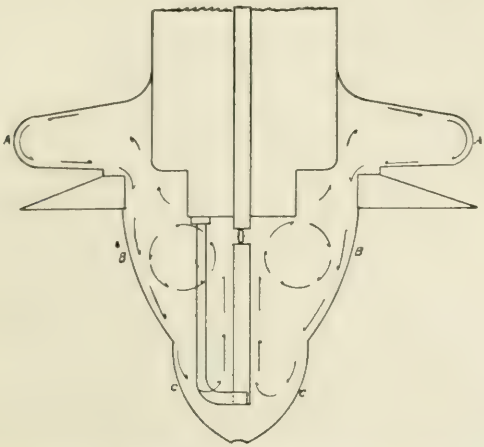


Fig. 12.—Sketch indicating path of gases from flame carbon arc in one type of lamp.

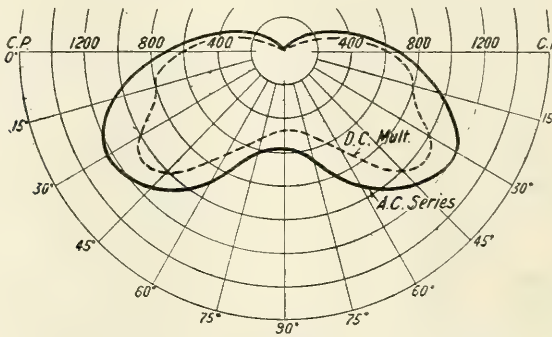
rates of consumption of the upper and lower carbons. In other words, the surface of the upper carbon over which the hot gases pass is very rapidly consumed by any free oxygen which may be in the arc chamber.

The life of a flame carbon depends upon its density, the current, the length of the arc, the composition, and above all, the tightness of the enclosure in which the carbon is consumed. Every effort should be made to maintain the enclosure as perfect as possible at all times. Only accurately ground globes, free from flaws at the globe seat, should be used; while the portion of the lamp which comes in contact with the globe should be made from a hard, strong alloy which will be affected as little

as possible by the fumes from the arc. To insure maximum life, it is necessary that all joints in the condensing chamber be maintained tight and that the condenser be removed as little as possible. Under commercial conditions, a life of from 15 to 20 hours per inch may be obtained from standard carbons.

LAMP PERFORMANCE.

Passing from the somewhat more theoretical considerations of the arc to the more practical point of operation and performance,



DISTRIBUTION CURVE OF CLUTCH TYPE FLAME-CARBON ARC LAMPS
Clear Inner and Alba Outer Globes. White Carbons.

A. C. SERIES

Terminal Volts 52	Amperes 10	M.L.H.C.P. 1000
Terminal Watts 425	Efficiency 93%	M.S.C.P. 655
Arc Volts 46	Power Factor 81.6%	M.L.H.C.P. Per Watt 2.35
Arc Watts 395		M.S.C.P. " " 1.54

D. C. MULTIPLE

Terminal Volts 115		M.L.H.C.P. 820
Terminal Watts 747.5	Amperes 6.5	M.S.C.P. 500
Arc Volts 70	Efficiency 61%	M.L.H.C.P. Per Watt 1.09
Arc Watts 455		M.S.C.P. " " .67

Fig. 13.—Comparative distribution curves of a direct current, 6.5 ampere multiple and a 10-ampere series alternating current flame carbon arc lamp.

the distribution curve of the flame arc deserves some consideration.

Fig. 13 shows comparative distribution curves of the direct current, 6.5-ampere, multiple lamp and the alternating current, 10-ampere, series lamp. It will be noted that the two distribution curves are very similar. The slight difference in shape between the distribution curve of the alternating current and the direct current lamps is due, mainly, to the long arc of the

direct current lamp and to the somewhat greater intrinsic brilliancy of the lower portion of the direct current arc.

It will be noted that these distribution curves indicate that a very considerable amount of light is radiated at angles above 45 deg., the maximum illumination occurring at approximately 30 deg. below the horizontal. For street lighting or for the illumination of large areas, this is a very desirable characteristic, and in comparing various lamps of the same general types, it is often desirable to rate the lamps on such a basis that the candle-power between the horizontal and 30 deg. below the horizontal will be given more weight than the candle-power at other angles. In other words, the total useful light flux represented by the candle-power at any given angle varies with the cube of the cosine of the angle.

From an esthetic standpoint, the flame arc is particularly desirable because of the relatively low intrinsic brilliancy of the light source and the comparatively large area from which the light is emitted; and this makes an illumination from the arc softer and less fatiguing to the eye. It also avoids to a large extent the harsh shadows which are so prominent with the enclosed carbon arc. In spite of the lower intrinsic brilliancy of the flame carbon arc, it is desirable to employ the diffusing glassware.

The distribution of energy in the spectrum of the flame carbon arc is peculiarly well suited for illumination which is intended to approximate daylight, although where the matching of color values is of special importance the carbons employed should be designed with this point in view. In the light from white carbons, the red and green wave lengths are found in very materially greater proportions than in the enclosed carbon arc or metallic flame arcs.

The efficiency of the flame arc as an illuminant is particularly high. The mean lower hemispherical candle-power per watt varies from 2.5 with white carbons and "Alba" glassware, to 5 mean lower hemispherical candle-power per watt with clear glassware. When opalescent globes are employed, the efficiency falls between these values. Yellow carbons may be obtained which give from 30 to 50 per cent. more light than the white carbons.

From an operating and maintenance standpoint, the flame carbon lamp is peculiarly suited for the illumination of city streets, as well as for factory lighting. The lamps require but little attention; the life between trims is approximately 100 hours, and the time and labor of trimming the lamps is small. Under efficient direction, one man could very readily trim and clean from 50 to 75 lamps per day. At each trimming period, it is desirable to carefully remove the "soot" from the globes and condensing chamber, while after each 1,000 hours of operation, the consumer should be renewed. Depending upon the care and efficiency with which the installation is maintained, the life of the globes varies from 2,000 to 5,000 hours. The importance of maintaining the globes clean and in good condition is frequently not sufficiently appreciated by operating engineers, and as a result, the light efficiency of the lamp is very materially reduced.

CONCLUSIONS.

A consideration of the points noted above will make evident some of the features which have been incorporated in modern flame carbon arc lamps and some of the difficulties which have been encountered and commercially overcome. At the present time, the flame carbon arc lamp is a commercial success and has stood the test of actual operating conditions. The field of the flame carbon arc lamps is continually expanding, and due to the increased prosperity of the period and the fact that engineering development has kept pace with commercial requirements, there seems to be little doubt but that the installation of flame carbon lamps will in the near future considerably outdistance the installation of all other types of large energy lighting units, including those used in the most utilitarian and busiest shops and factories, as well as those employed for highly ornamental street or parkway lighting.

DISCUSSION.

Messrs. W. R. Mott, R. B. Chillas Jr., and A. T. Baldwin (communicated): Several points in Mr. Darrah's excellent paper bring up questions which we desire to discuss briefly.

Along with the other differences mentioned between the flame arc and the magnetite arc it may be well to bring attention again to the fact that the nature of the positive flame electrode largely determines the color and candle-power of the arc, while with the magnetite arc the negative is the determining factor.

An examination of oscillograms of flame arcs will show that the less-than-unity power factor is the result of a distortion rather than a displacement of the waves. The high power-factor of the flame arc is due to the ease with which the current is re-established through the hot gases after each reversal of current. Since the light flux is largely dependent upon the current it is evident that the least variation or flicker in the light will be found in the arc of highest power factor. As indicated in the paper the starting voltage of the flame arc is very low. In fact it is much lower for the flame arc than for either the enclosed arc or magnetite. In these respects the flame arc in general has a marked advantage over the other arc illuminants. Certain types of commercial carbons possess these properties to a far greater degree than others. Such carbons are particularly useful on low frequency (25 cycle) circuits, and in lighting shops containing moving machinery, especially if the movement of machine parts and the cyclic variation of the light are nearly synchronous.

The alternating current flame arc possesses one rather striking advantage over the plain carbon arc because it shows less flicker at lower frequencies. In the plain carbon arc the electrode which is positive at any instant is giving out most of the light. This means that on 25 cycles the light in one direction passes through a maximum 25 times per second. In the flame arc, where the light comes from the arc stream itself, the corresponding figures are 50 times per second, or far beyond the critical flicker frequency of the eye.

The best arc voltage to be used is determined to a large extent by other factors taken in conjunction with those pointed out by Mr. Darrah. As the arc voltage and consequently the arc length

is increased at constant current a point is reached at which the candle-power increase is not as fast as the voltage increase due to the greater cooling of the arc and the steadiness begins appreciably to diminish. Carbons can be made which will operate satisfactorily at the higher arc-voltages but such operation is obtained at the sacrifice of candle-power due to the increased amount of "sustainers" required at the expense of the quantity of "illuminants" present. This follows from the fact that the total amount of flaming materials in the carbons is limited by the slagging tendency so that an increase of one type of material must be accompanied by some decrease in the others. Taking all things into consideration, it will be found that the highest candle-power, the best steadiness and reliability will be obtained in 110 volt multiple lamps when the arc voltage does not exceed 65 and the current not lower than 6 amperes. For series lamps and alternating current multiple lamps with auto-transformers, 40 to 45 arc volts gives good service when the current is not less than 10 amperes. In general, however, a flame carbon can be made to operate satisfactorily commercially over a very wide range of current and voltage for a given lamp, but at present there is no one carbon that will meet all conditions satisfactorily in every way in all lamps.

The current densities within the arc will be found to vary quite widely. The cross-section which the arc assumes is that which will maintain the equilibrium between the energy input and the output of light and heat. The size depends on so many factors, such as the mutual attraction of the current filaments in the arc stream, the volume of gas produced by all of the different chemicals at the various temperatures and pressures, the repulsion of similarly charged electron, that we can say only that the given current densities have been found. That they are also satisfactory is very fortunate. The diffused arc mentioned, is an effect obtained only occasionally in some direct current arcs; never in alternating current arcs. It is of much lower efficiency than the normal direct current arc which has a positive crater current-density of the order of 300 amperes per square inch. We have found the usual tendency to be that arcs of the higher current densities give higher efficiencies.

The use of magnesia blocks in the condensing chamber to prevent globe etching can hardly be considered successful. Toward the end of the trim-life the blocks become covered with dust which prevents the complete absorption of the harmful gases and so permits them to attack the globes. The blocks must be renewed from time to time, which introduces an additional cost into the maintenance account. With properly designed carbons, the magnesia blocks can be omitted and globe etching does not occur.

MR. F. A. VAUGHN (communicated): Just one thought appears in connection with the author's reference in his first paragraph to the relegation to the scrap pile of old equipment, especially enclosed arc lamps, and old types of the prismatic glass reflector. This very point is sometimes a matter of considerable consequence to illuminating engineers who wish to do their duty not only to their client in any particular case but to the commonwealth at large as far as the great movement for conservation of vision is concerned.

The client naturally wishes to obtain as great an advantage in the disposal of the old equipment as possible and the suggestion is almost always presented that these units and these reflectors are good enough for other installations, and he usually makes every effort possible on his own part and desires the engineer to do so also, to dispose of the equipment to other unsuspecting and unknowing users of illumination. The illuminating engineer's duty to his client is, perhaps, to obtain the advantage for his client in so doing, but his duty to the commonwealth is to use a strong, heavy sledge hammer on the entire equipment and thus put an end to its career as a destroyer of human vision, not only as far as that specific client is concerned but also the entire universe.

It thus devolves upon the illuminating engineer to convert his client to enough sympathy in the conservation of vision movement to feel willing to allow the whole equipment to be disposed of for all time.

THE ILLUMINATION OF MOTION PICTURE PROJECTORS.*

J. FRANK MARTIN.

Synopsis: After outlining the operation characteristics and requirements of the light sources of projection lamps, the color of light, and the character of screen best adapted to projecting motion pictures, this paper is concluded with a brief discussion of the question, Does the motion picture cause eyestrain? Observation, the author states, indicates that constant viewing of motion pictures tends not only to develop the semi-voluntary muscles of the eye but to give them greater endurance and more rapid action. He adds, though, that pronounced flicker in pictures may lead to over-stimulation and injury. The discomfort and irritation sometimes experienced by patrons of motion pictures, caused by unsteadiness of the pictures and defects in the films, indicates so much fatigue which usually recedes without any resulting injury. The author suggests an examination of the eyes of lantern operators to determine the nature and extent of the effect of motion pictures on the eye.

The motion picture is now recognized as an educational factor second in importance only to the printing press. It is a development of the last twelve years and like other great inventions which possess novelty and meet a demand of the public, the introduction has been accompanied by a disregard of scientific principles and the necessary standardization to secure the greatest efficiency.

The magnitude of the industry may be judged by a consideration of the fact that there are more than twenty thousand motion picture theatres in America, having an average daily attendance of twenty million people and a maximum demand for electric current in excess of sixty thousand kilowatts, which about equals that for lighting a city such as Philadelphia, Boston or St. Louis.

This attendance of these theatres compared with the total number of people who are habitual readers by means of artificial light shows, that if the general impression that the motion picture seriously affects the eye is correct, the illuminating engineer is confronted with a problem which is not receiving the attention which its importance demands.

* A paper read before a meeting of the Pittsburgh section of the Illuminating Engineering Society, April 18, 1913.

THE SOURCE OF LIGHT FOR PROJECTION.

From the beginning, wherever electric current was available, the electric arc has been the only source of light considered. The requirements for a satisfactory projector iluminant are: first, as near an approach to a point source of light as is possible; and, second, the most intense source of light available. The carbon arc is the nearest approach to these requirements, and the modern motion picture projector has practically been built around the electric arc.

CHARACTERISTICS OF THE PROJECTOR ARC.

Fig. 1 shows the voltage at the arc on both direct and alternating current, using a type of carbon which is widely used, at varying current densities. The arc gap, size of carbons and align-

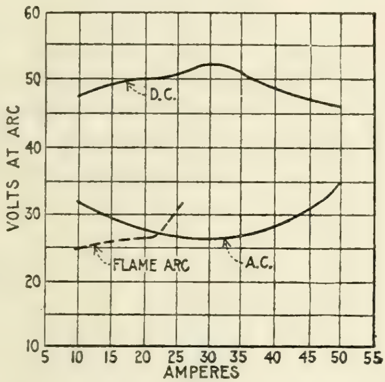


Fig. 1.—Characteristics of projector arcs.

ment of carbons was adjusted for each current value so as to give the most stable performance. The dotted line in Fig. 1 represents a special flaming arc carbon, and the curve is representative for both alternating and direct current.

ALIGNMENT AND DIMENSIONS OF CARBONS.

Fig. 2 illustrates two methods of aligning the carbons and the distribution of light resulting therefrom. These settings represent the extremes between which satisfactory performance of the arc can be secured. On direct current the top carbon must invariably be made the positive electrode of the arc so as to direct

the maximum flux of light in a horizontal plane. On both direct and alternating current, the top carbon gives the most light by virtue of its position in the draught of intensely heated glass from the arc. The top carbon also burns away faster from the same cause.

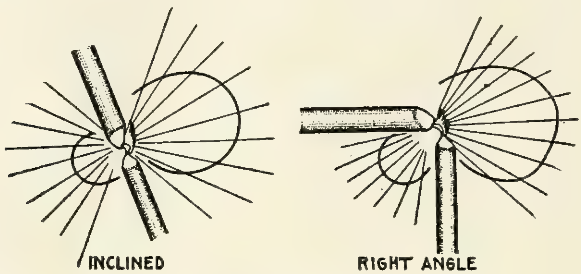


Fig. 2.—Alignment of electrodes.

It is very important that the size of the carbon and the relative diameter of the core and shell be closely regulated to the current density. Both the stability of the arc and the intensity of light may be materially increased by varying the dimensions of the carbons used.

THE MECHANISM OF PROJECTOR LAMPS.

The modern projector lamp retains the elementary construction and principle of the most primative electric light. Fig. 3 and 4 illustrate the most approved forms in use at the present time. Hand operated lamps are universally used on account of it being impossible to construct a lamp which will automatically center the rrc in the lens axis and compensate for the wandering of the arc.

THE PERFORMANCE OF PROJECTOR ARCS.

Fig. 5 shows the relative candle-power of the arc on alternating and direct currents at varying current densities. Readings were made in a horizontal plane, the size of carbons, alignment and arc gap were adjusted in each case to give the steadiest performance. Attention is called to the termination of the curves for the right angle and flaming arc at about 27 amperes, beyond which point the magnetic blow out effect in this method of aligning the elec-

trodes has such a value that the arc is lengthened, becomes very unsteady and consequently unsatisfactory.

For the same current density, all forms of the arc have a much greater intensity on direct current than on alternating current.

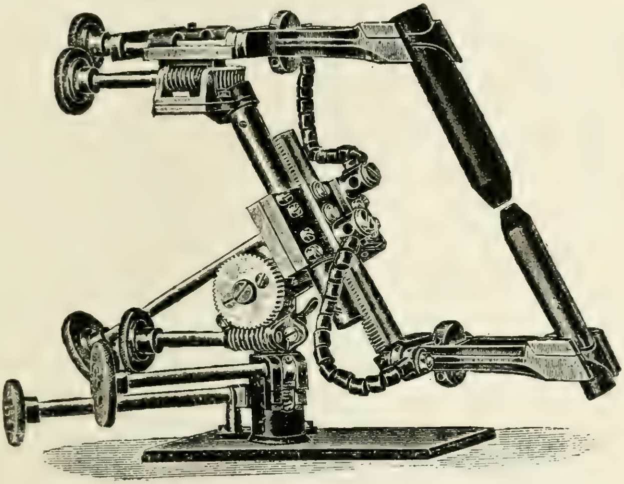


Fig. 3.—Straight line lamp.

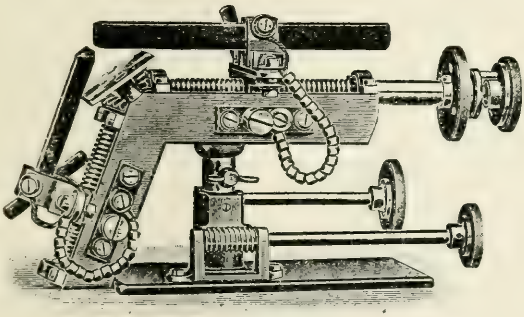


Fig. 4.—Angle lamp.

This condition is due to the pronounced crater of the direct current arc and the ease with which the flux of light from this crater may be directed by the alignment of the electrodes.

COLOR OF LIGHT.

The color value of the light used in projection is of small importance unless it is considered from an esthetical viewpoint in conjunction with photographic processes. However, under present conditions the combination of effects arising from the use of

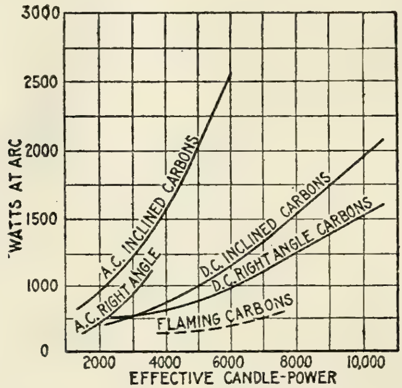


Fig. 5.—Performance of projector arc.

arcs giving a bluish light and very contrasty photography gives exceedingly harsh impressions. The use of an arc in which yellow is the predominating color would make a material improvement.

THE LENS SYSTEM OF PROJECTORS.

Many different combinations of lenses have been experimentally

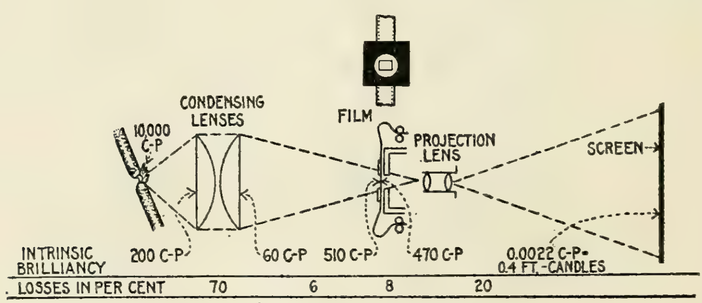


Fig. 6.—The lens system of projectors.

developed but no radical changes have been made in the earliest form of lens used in the magic lantern. The lens system and the

losses therein are illustrated in Fig. 6. It has been built up with a point sources of light as a basis consequently the low efficiency of 10 per cent. is not surprising and there is apparently a great opportunity for improvement.

REGULATION OF THE PROJECTOR ARC AND METHODS OF CONVERTING ALTERNATING TO DIRECT CURRENT.

Within certain limits of projection which may be described as the illumination necessary to project an image not exceeding one hundred square feet in area, direct current through a resistance is not highly preferable to alternating current supplied through an auto-transformer, the service voltage being equal in each case at

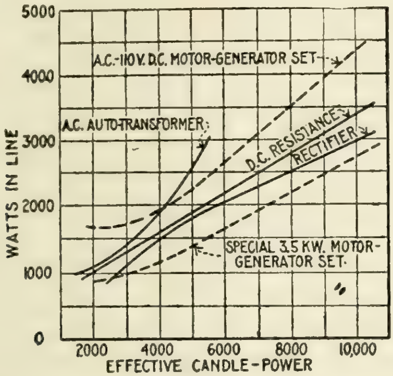


Fig. 7.—Performance of projector arc on alternating to direct current converters.

110 volts. Many forms of self-regulating motor generator sets, autotransformers and rectifiers, all having a regulation characteristic closely approaching that of a metallic resistance, are in use. Fig. 7 shows the comparative efficiency of the arc operating in conjunction with these machines. All the readings were taken after setting the lamp for the most satisfactory operation.

The majority of motion picture theatres use auto-transformers of high reactance, which are manufactured and marketed under various trade names.

For the reason that the use of alternating current gives a very low efficiency at the arc, requiring heavier current for a given illumination and an accompanying increase in heat dissipated and under average conditions will increase the inherent flicker of the

projected image, it is highly desirable to standardize the apparatus so that direct current is supplied to the projection lamp. A careful analysis indicates that this apparatus should be a motor-generator set, the motor allowing of substitution for either alternating or direct current at different voltages, and the generator having a capacity of 3.5 kilowatts, 65 volts, direct current, compound wound and designed to deliver 175 per cent. full load for a five minute period of each hour. One or more projection lamps, each connected through a small resistance to give the necessary ballast, could be supplied from this machine and could be operated simultaneously for short periods without affecting the other. The field rheostat and lamp ballast should be placed conveniently near the operator so that the intensity of light can be regulated for the varying density of the films. This machine could be universally used with an improvement in economy and quality of projection. The relative efficiency of this machine is also illustrated in Fig. 7.

PROJECTION SCREENS.

The low intensity of illumination, which is less than 0.4 foot-candles on the average motion picture screen, immediately leads to the conclusion that improving the illumination is largely a matter of increasing the intensity of the light source and the efficiency of the lens system. This conclusion is also apparently substantiated by the fact that the difference in the efficiencies of the available reflecting surfaces allows of no great increase in reflecting efficiency. However, due to the fact that the eye is very much more susceptible to changes in illumination at low intensities than at those ordinarily experienced, it is possible to apparently double the screen illumination by increasing the efficiency of the reflecting surface only 10 per cent.

In an effort to satisfy a public demand for more wholesome and better lighted surroundings, there has been developed a number of improved screens. There are two distinct types of these screens: one consists of a smooth surface dressed with aluminum powder and lacquer; the other is a dressing of the whitest and most opaque paint obtainable, applied to a smooth surface or to the back of a large piece of plate glass. The

aluminum dressed screen closely approaches the efficiency of a low grade amalgam backed mirror and unless the surface is pebbled or roughened, the image on the screen is not entirely discernible to a spectator sitting to one side, without the angle of incidence. This screen must also be mounted in a perfect flat plane to avoid a serious glare and on account of the metallic tint gives color distortion. A piece of plate glass, backed with an opaque white surface, although costly, is the ideal screen. This construction gives a perfectly smooth surface, fine grained and gives the highest efficiency allowable in securing satisfactory definition. White oil cloth stretched on a rigid frame is less durable but almost as satisfactory.

THE ILLUMINATION OF AUDITORIUMS WHERE PROJECTION IS USED.

The first consideration is to avoid all sources of light which will cause glare. Wall brackets fall in this category and should never be placed in the range of vision, between the spectator and the screen. Indirect illumination from chandeliers or cove lighting is highly preferable as it best avoids glare.

The intensity of illumination should be graduated from the screen outward toward the rear of the auditorium and should average about 0.2 foot-candle at the level of the backs of seats. The value at the rear where the movement of spectators is congested may generally be increased to one foot-candle with satisfactory results.

POSSIBLE METHODS OF IMPROVING PROJECTION.

Experiments with a view to adapting the flaming arc to projection have been made and have demonstrated that an increase of approximately 60 per cent. can be made in the illumination up to a current density of 20 amperes. The excessive length and large area of the flame, which give practically all the light, is a recession from the desired point source and makes it necessary to use the right angle alignment of electrodes which determines limitation of the above current value.

Another method allowing of an increase in the efficiency of the lens system appears to be in the use of a metallic filament lamps having a short heavy filament arranged with a reflector and

lens as shown in Fig. 8. The lamp may be worked at a considerable over-voltage and, by interrupting the current periodically in synchronism with the movement of the film, the overshooting

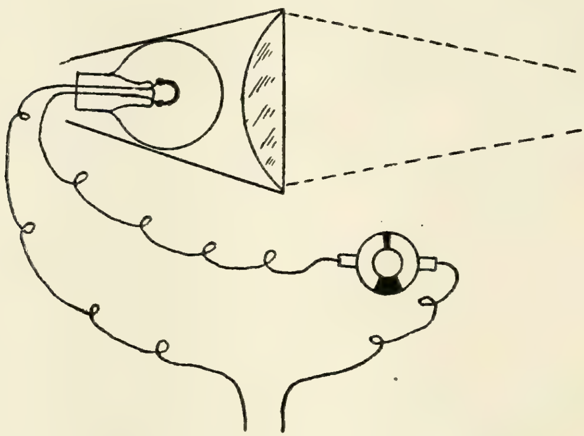


Fig. 8.—Special lighting system for projectors.

phenomena of the lamp will increase the illumination and the present sector shutter can be eliminated.

DOES THE MOTION PICTURE CAUSE EYESTRAIN.

It is believed that standardization to secure commercial efficiency should be considered secondary to the correction of physiological defects. The illuminating engineer in his work in the field of motion picture projection should give particular attention to the possibility of evil effects accruing to the eyes of those who witness picture performances.

Before going further, it must be understood that the following analysis is not made from the viewpoint of the ophthalmologist with a full understanding of the principles of physiology involved, but is rather from the viewpoint of the layman. If this paper serves the purpose of attracting attention to the subject, it will have served its mission.

Eyestrain, discomfort and permanent injury may for practical purposes be divided into two classes: causes which affect the muscles of the eye, and those which cause deterioration of the nerve structure.

In considering the effect of motion pictures, two sources of evil are found to be practically absent. First, there is little danger from intense light entering the eye and there is no glare unless foreign sources of light are within the range of vision; therefore there can be no deterioration of the nerve structure. Second, when viewing the image on the screen the involuntary muscles controlling the focus of the eye lens are inactive and there can be no evil influence on these muscles. This leaves two possible conditions which may have an injurious effect. The most common fault is the flicker which involves the basic principle of motion picture projection. The other fault lies in the common but unnecessary evil of unsteadiness in the image on the screen, which is the result of defective methods in the manufacture of film or in the maintenance of the projector mechanism.

The effect of flicker is confined to the involuntary muscles which control the action of the iris. The natural action of the iris is to close very rapidly and open slowly. When looking at a motion picture the pupil is contracted to a somewhat smaller opening than when viewing a still picture having the same illumination. When flicker is pronounced, the pupil may be observed to tremble slightly as if attempting to follow the fluctuation of light. This may lead to over-stimulation and permanent injury.

The discomfort and irritation of the eye sometimes experienced by the patrons of motion picture theatres is due to the unsteadiness of the picture and blemishes of the film used. These faults affect the semi-voluntary muscles which control the movement of the eye ball and the discomfort is due to fatigue which recedes without apparent injury. Observation indicates that constant viewing of motion pictures tends to develop these muscles, giving them greater endurance and more rapid action. To secure light on the subject it is suggested that observations at first be confined to motion picture operators who as a class of tradesmen do not show the evil effects that would be expected.

DISCUSSION.

Dr. Ellice M. Alger (communicated): In discussing Mr. Martins very interesting paper I must confess at the outset that my personal experience with moving pictures has been more theoretical than practical because to me, as to many other people, they have been so productive of strain and discomfort and headache that I avoid them.

It does not of course necessarily follow that, because they cause discomfort and fatigue, that they also cause organic damage to the eyes provided the fatigue is kept within the individuals physiological limits. That point can only be determined, as Mr. Martin suggests, by a careful observation of the effects on the eyes of employees and others whose exposure is a continuous instead of an occasional one.

Neither do I doubt that even in matters of fatigue and strain most individuals would with practise develop a great increase in their ability to compensate for them. But I do feel reasonably sure that the strain imposed by frequent watching moving pictures, when superimposed on the fatigue caused most of us by our customary ocular tasks, very frequently passes beyond physiological limits and must eventually produce deterioration.

Furthermore it seems to me that many of the factors which cause fatigue cannot be done away with but are inherent in the pictures by reason of their being "motion" pictures.

I am inclined to disagree with the author's opinion that there can be no strain of any account caused by the action of the ciliary muscles in focussing, since the screen is some distance away from the eyes and that distance an unchanging one. Even with a perfectly normal eye the intentness with which one must watch a moving picture prevents in large measure the complete muscular relaxation which at frequent intervals should rest our eyes. But very few of us have normal eyes. Most of us are far sighted or astigmatic and many of us have muscular defects as well. We have to focus to see even distant details distinctly and while this muscular effort need not be very great for the moment the constant rapid changes on the screen make it almost continuous.

In real life we see things momentarily much as a painter would paint them. Things in the plane for which our eyes are adjusted

are clear and distinct while those out of focus are more or less blurred, so that we may be only partly conscious of them. In the moving picture, things, which in nature were in different planes, are reproduced on the one plane of the screen and so in a sense are forced upon our consciousness simultaneously. As a result there are a multitude of distracting details in range of our eyes at one time and we regard a moving picture with an unwinking intentness which is very rarely called for in ordinary life.

Neither do the extrinsic muscles of the eyes escape strain. Even if the picture were an unchanging one the mere matter of watching it implies the co-ordination of the eyes which depends on the extrinsic muscles. But in the moving picture motions which are intended to appear to us smooth and continuous as they were in life really proceed by a very rapid succession of stops and starts and the actions are usually completed in a very much shorter time than they took in real life. Possibly by being less economical in the matter of film the jerky motion of the figures in the picture could be largely done away with but in practice we are always conscious of and instinctively try to follow these movements. As a result our extrinsic eye muscles are in a state of steady nervous and muscular tension which is both abnormal and fatiguing.

But the most obvious cause of eye-strain in watching moving pictures are the rapid jerky motions of the whole picture, the occasional showers of light flashes, and the variations in light intensity which give us a sensation of flickering light. The first two are said to be due to imperfections in the film and can be done away with by more careful construction, but the flicker seems to be inherent in the business. I should say that the disagreeable effect of flicker was only partly due to its effect on the iris. Light falling on the retina causes a stimulation of a centre in the brain which in turn causes a contraction of the pupil. If the light remains steady the retina becomes adapted to it and the pupil dilates somewhat. When the light stimulus is removed the pupil dilates pretty widely. This whole process requires an appreciable time and the degree of contraction depends not only on the brightness of the light to which the eye is exposed but also on the degree of illumination to which it had previously become adapted. So that a light of rather low intensity, provided the

room is comparatively dark, may cause marked contraction. But the flicker of the moving picture applies and removes the stimulus of bright light much more rapidly than the muscle can respond, and as a result the pupil remains in a state of rapid oscillation which is not synchronous with the actual variations in light intensity. The outcome is not only fatigue of the sphincter pupillae but a state of nerve exhaustion from the too rapid discharge of nerve impulses.

Another difficulty which has to do with the adaption of the eye to light is this. All observers are agreed on the retinal fatigue that comes from having one portion of the retina exposed to light while the rest of it is in comparative darkness. A strong incandescent light in a dark room is too bright to look directly at while if the room be filled with daylight the bulb seems hardly visible. In the moving picture one is looking intently at a screen on which the light may not be intrinsically very intense but, by comparison with the surroundings, seems very bright indeed. It would probably be very much easier for the eyes of the observers if the theatres were lighted in such a way that while no direct light fell on the eyes the general illumination was as good as was compatible with visibility of the screen.

Mr. F. A. Vaughn (communicated): The author's discussion of eye-strain, discomfort and permanent injury caused by the motion pictures would, it is thought, lead one to suppose that it was a matter which could be dismissed without very great concern, as the troubles, when apparent at all, are caused, according to the author, by undue "unsteadiness of the picture and blemishes of the film used". While the discussion may be accurate as far as it covers the case, it is believed that it should be pointed out that there have been severe cases of ocular disturbances cited by opthalmologists and the subject is of enough concern to have received attention in the *California State Journal of Medicine* in August, 1912, under the subject of "Ocular Disturbances caused by the Cinematograph" through the authorship of Morton E. Hart, M. D., San Francisco. Dr. Hart discusses it in part as follows:

Ocular disturbances due to the cinematograph have, up to the present time, received practically no mention in medical literature. It seems strange that this should be the case, for no doubt it has fallen to the

lot of almost every oculist, particularly in the large cities to have seen and treated many patients suffering from this new disease. And there are very good reasons that there should be ocular disturbances from this new plaything of the people. * * *

The ocular disturbances, classified under the generic term of "cinematopthalmia," are really disturbances of vision due to traumatism, and are matters of degree. The process is the same in all of the conditions. There are those cases which are merely transient in their disturbance. When the picture is first thrown on the screen, the individual is inconvenienced by photophobia and a few tears. He closes his eyes and these symptoms soon pass away after a few seconds of repose, and the retina accustoms itself to the new condition of affairs. A further degree is of longer duration; the retina cannot adopt itself to the fatigue imposed on it and each time the individual opens his eyes, the symptoms reappear. It is impossible to continue the spectacle. After leaving the theatre, the disturbance still persists and in addition to the mild photophobia and lacrymation there ensues a slight reddening of the conjunctiva. A few hours, or at least a night's rest, will return the eyes to their normal tone.

In the third degree of disturbance, the symptoms are more severe and the return to the normal somewhat prolonged. Here the phtophobia, lacrymation and conjunctivitis persist for several days and in addition, we have a smarting and itching of the eyes.

In the very severe cases, besides the inflammation of the conjunctiva with its attendant symptoms of lacrymation and phtophobia, we have very definite asthenopic symptoms, both accommodative and retinal—the former due to the ciliary strain and the latter due to a hyperesthesia of the retina. The distant vision remains normal. Under examination these patients are found to have no error of refraction or lesion of the fundus. A case in question may here be cited:

E. R., female, age 16, was brought to me with the following complaint: Eyes burned and itched and the lids were red, particularly at night. Reading was impossible on account of blurring of the page. No headaches. This condition would clear up after a night's rest, to reappear again at frequent intervals.

On examination a slight reddening of the conjunctiva was found and under a mydriatic an error of one degree of hyperopia, which was corrected. The near point was normal, showing no error of accommodation. Of course this was tested before using the mydriatic. No lesion of the fundus was found. Unfortunately the patient could not be seen during an attack.

After wearing the glasses for several weeks, the patient reported, stating that the condition had not improved. She was then closely questioned and it was found that it was her habit to attend a moving picture show at least four times a week after school and unbeknown to her mother. She was forbidden this amusement and the condition entirely cleared up.

Fortunately these ocular disturbances are not serious and will clear up under simple collyria and rest.

The question will naturally arise, how can we do away with the cause of the trouble?

First: The films must be perfect and free from all imperfections.

We have all noticed the scratches on the pictures, particularly at the end of the reels, due to careless handling. When we realize that the average picture thrown on the screen is about 97,000 times larger than the original size of the individual film, we can appreciate that even the smallest blemish on the films will be tremendously magnified on the curtain and will have a correspondingly bad effect on the eyes.

Second: The illumination must be steady, must not vary and must neither be too bright nor too dim, for this causes fatigue.

Third: The speed with which the films are turned must be regular. Any irregularity will have a tendency to cause ocular fatigue.

Fourth: The position of the spectator is very important and should receive proper regulation at the hands of the authorities. First of all, there should be no seats placed at the sides of the auditorium. Every seat should be in direct line with the curtain. This will do away with the distortion of the picture. Anyone who has had the experience of sitting on the side, can appreciate the intense strain and fatigue placed on the eyes.

No seat should be placed nearer than twenty feet from the screen and further if practicable, depending upon the size of the picture on the curtain. This will do away with any accommodative effort on the part of the spectator and thus will reduce the fatigue to a minimum. The nearer the screen the greater the fatigue, so the seats at the rear of the auditorium are the best.

Some people are very susceptible to the influence of motion pictures, not being able to sit through one performance without headache or severe eye-strain. It will thus be seen that quite painful and somewhat serious cases of ocular disturbances have been caused and probably will be caused in the future by motion pictures and that, while this may be due to imperfections in their operation or presentation, these imperfections will probably obtain in the future as well, and this subject should therefore receive serious consideration from ophthalmologists, as well as illuminating engineers, at least until the imperfections are eliminated. After that it may be determined whether there is still remaining serious objection to them from the standpoint of ocular comfort.

Dr. P. W. Cobb (communicated): The motion picture man has a set of problems pretty much his own. Mr. Martin's paper touches some of them in a way which interests me. I am surprised at his statement that the illumination on the screen is only 0.4 foot-candle but such surprises are many for one who attempts to estimate illumination from visual impression. The motion picture auditorium has to have a low general illumination, just

enough for a person whose eyes are light-adapted on his entrance to the theatre to see to take a place. Mr. Martin places this at an average of 0.2 foot-candles. This sets the pace, as it were, for the eye and determines the illumination necessary upon the screen in order to make the pictures stand out brilliantly. The question of contrast enters here as an important factor; the contrast between the picture on the screen on the one hand, and on the other its surroundings, the seats, walls and ceiling of the theatre. The surface brightness of these latter is a factor in determining the visual brightness of the screen, equal in importance to the lumens per unit area of the screen itself.

Speaking of contrast, I should like to ask if tinting the general illumination of the room has ever been used to modify the apparent color of the screen. For instance, I should expect that by tinting the lamps in the auditorium a bluish color, the pictures could be made to appear yellowish, or by making the lamps greenish the screen would show a tendency to a rosy pink. A small amount of tint in the general illumination would be enough, I should think, to get a pronounced contrast effect on the screen.

It is gratifying to note that the question of eye-strain has been considered. At 0.4 foot-candles the question of too intense light cannot merit discussion and glare can be ruled out. What should be, and is, considered is flicker and unsteadiness of the image.

I cannot agree with what Mr. Martin says as to the effect of flicker being confined to the muscle of the iris which controls the pupil.

It has been shown that when the eye is kept in the dark and illuminated by a momentary flash of light the reaction of the pupil is delayed for something like half a second. The contraction follows and the pupil does not begin to dilate until a lapse of about 10 seconds. Such movements are altogether too slow to follow the flicker of a motion picture which has a rate say of 10 per second or thereabouts. As a matter of fact the pupil is always undergoing slight fluctuations in size in the absence of all changes in light, a fact which can be verified by anyone who cares to examine his own pupil by means of a mirror and a lens of low power. It would appear to me that the examination of the pupil under strongly flickering light would be attended

with great uncertainties and make it difficult to estimate the amount of fluctuation and compare it with the normal.

Nevertheless, flicker is undoubtedly disturbing to the eyes, a fact which was much made use of in getting electric incandescent lights into use when they were first introduced to the public. The exact way in which flicker embarrasses the eyes is, I believe, still not known.

By far the most serious evil of motion pictures seems to me to be unsteadiness of the image, which I am glad to know is an unnecessary one. A person leaving a motion picture theatre to go back to an occupation not especially involving the eyes may, as Mr. Martin says, find the difficulty which he experienced while viewing the pictures to disappear rapidly, if he continues to notice it at all. But it must be far different with one whose calling depends on close application of the eyes. Here the muscles of the eye, which have been subject to all sorts of surprises in trying to fix upon a wavering image are taken away from this only to do more work of a similar kind, reading, sewing or what not, which calls for the finest sort of co-ordination of the twelve extremal muscles of the eyes. When one reflects upon the delicate balance of these muscles, and the incessant and rapid movements which they must accurately carry out in fine eye-work it seems impossible that such a shaking up as they get in attempting to fix an image which jerks about irregularly upon the screen should not unfit the eyes to a greater or less extent for subsequent work. It is therefore good to hear that such pictures need not be, and to feel that they will soon be eliminated from the motion picture world.

As to the suggestion that observations be made upon motion picture operators to detect changes in the eyes due to the pictures I wish to ask does the operator himself watch the pictures at all attentively? My feeling is that he does not, or at most, watches them "out of the corner of his eye" only to detect gross defects in the film or in the action of the machine. It is an open question in my mind whether he would suffer as much in a week as the casual visitor to his theatre does in an hour.

The visitor is eager and intensely interested in the story of the picture (which is a very old story to the operator) and applies his

attention and his eyes closely to the image. It is just this close attention which whips up the eye-muscles to the task of observing the image and spurs them on to their own confusion if the latter be unsteady.

MR. EDWARD L. SIMON: (communicated): This paper is indeed food for extended investigation and the time is now ripe for a uniform and scientifically designed and arranged source of light for projection.

The large film manufacturers have and are expending hundreds of thousands of dollars for the improvement of the films and these films when delivered to the exhibitors are mechanically perfect. This does not apply to the small manufacturers and the audience is not able to judge between a good and bad film owing to a defective projecting machine.

The projecting machine of the future must be a presicion machine mounted on a concrete or some other rigid foundation. The light should be a cold light and to get rid of the flicker the screen should never be dark, which is now the case sixteen times every second. It is not right that a beautiful picture should be spoiled in its projection by being run through a loose and untrue projecting machine with a projecting light that is operated according to the individual operators ideas. It will not be long before the manufacturers will be compelled to insist upon rigid enforcements in the way of perfect projecting machines and proper light source.

The film as used to-day is enlarged one hundred and fifty diameters. The large productions in the future will not be enlarged more than fifty diameters and the audience will have the pleasure of looking at pictures as steady as stereoptican views.

MR. LOUIS C. SMITH (communicated): In my experience in projecting pictures, I have found that considerable attention should be paid to the regulating of the quantity of light for different films, slides, etc. I do not apply this to dense films entirely, but to various films of varying subjects. Recently, I projected some cloud scenes, the effect of which when lighted with all the available energy was so contrasty that it was unnatural. In general, though, I have found that the general public like the bright contrasty photographs and motion pictures. More

attention seems to be paid to the theme of the picture than the details of it. This is evidently so partly because defects in the pictures are so usual.

Although large amounts of money are spent in the moving picture field, the theatres seldom get good complete projection outfits; then again the operator usually does little more than turn the crank mechanically; he pays little attention, if any, to getting the best results out of his apparatus.

There are subjects which require great speed and others that should not be projected so rapidly; usually all are projected alike. Many things depend directly upon the taste and experience of the operator.

Some of the most pleasing slides have been projected by a calcium light. This seems to be due to the yellowness that the author speaks of. No doubt a yellowish bright light would be suitable for many films.

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Council Notes.

A meeting of the Council was held in the general offices of the society, 29 West 39th Street, New York, May 9, 1913. Those in attendance were: Preston S. Millar, president; George S. Barrows, C. O. Bond, J. W. Cowles, Joseph D. Israel, general secretary; A. E. Kennelly, Norman Macbeth, L. B. Marks, treasurer; W. Cullen Morris, W. J. Serrill, R. C. Ware and Arthur Williams.

The Executive Committee reported that it had held a meeting April 25. The business transacted by the committee is given in the following minutes of the meeting:

It was decided to accept the invitation of the Pittsburgh section to hold the 1913 convention of the society at Pittsburgh in the fall.

After a general discussion of convention plans President Millar was directed to appoint a general convention committee. It was understood that the general committee might appoint such sub-committees as may be required to care for the various details and arrangements of the convention.

A draft of the society's conspectus, submitted by Mr. Macbeth, was discussed informally.

The above report was received and concurred in by the Council.

Vouchers 1273 to 1314 inclusive, covering May bills aggregating $1,086.70, which had been approved by the Finance Committee were authorized paid. A monthly report on the society's finances and membership was received from the general secretary. The expenses of the first four months of 1913 were said to have totaled $2,823.29. The membership including the additions and defections presented at the meeting was said to have totaled 1,363 members. The membership at the beginning of the year was 1,335.

Reports on section activities were received from the following vice-presidents: W. J. Serrill, Philadelphia; J. W. Cowles, New England; Norman Macbeth, New York; Howard S. Evans, Pittsburgh, and James Cravath, Chicago.

The Section Development Committee reported that it had completed a guide on section management which would be issued shortly.

The chairman of the Committee on Papers reported tentatively on the program of papers for the 1913 convention.

A brief and informal report on the progress of plans for the 1913 Convention was received from President Millar. The following appointments of the president to the Convention Executive Committee were approved: C. A. Littlefield, chairman; M. C. Rypinski, D. McFarlan Moore, O. H. Fogg and Thomas S. Henderson.

Additional appointments to committees made by the president since the last Council meeting were approved.

The following committee of five tellers was appointed to count the

ballots of the annual election: G. B. Nichols, chairman; L. J. Lewinson, A. L. Powell, Raymond W. Stafford and Thomas Scofield.

Mr. L. B. Marks presented an oral and informal report of the progress of the plans of the Gas Congress which is to be held in San Francisco in 1915. Mr. Marks is the representative of the society on the committee which is to plan the Congress.

Mr. L. B. Marks chairman of the Committee on Factory Lighting Legislation reported that Governor Sulzer of the State of New York had signed on April 17, Bill No. 26 which is entitled "An act to amend the labor law in relation to protection of employees operating machinery, thus creating machinery and the lighting of factories and work rooms." A section of this bill relating particularly to the lighting of factories, passage-ways and work-rooms was drafted in accordance with recommendations made by the committee. This section of the bill was printed in the April issue of the TRANSACTIONS.

Dr. A. E. Kennelly reported orally for the Committee on Nomenclature and Standards. He said that a written report would be forthcoming from the committee shortly.

Section Notes.

CHICAGO SECTION.

At a meeting of the Chicago Section in the auditorium of the Western Society of Engineers, May 14, Mr. M. Luckiesh of the National Electric Lamp Association, Cleveland, gave a lecture on "Light and Art." The lecture, which was accompanied by a series of well planned demonstrations showing the effect of direction, and quantity and quality of light on objects of art and design, proved to be intensely interesting to the forty members and guests in attendance. The lecture had been given before meetings of several other sections of the society.

At the June meeting, which will probably be held on the 18th, Mr. Arthur J. Sweet will present a paper on car lighting.

NEW ENGLAND SECTION.

The May meeting of the New England Section was postponed. No date or program has been scheduled for a June meeting.

NEW YORK SECTION.

Before a largely attended meeting of the New York Section, May 8, Mr. Bassett Jones, Jr., gave a very interesting lecture and series of demonstrations on theater lighting. The meeting was held in the Clymer Street Theater, Brooklyn, through the courtesy of the proprietors. The uusal monthly dinner at Keene's Chop House, preceded the meeting.

PHILADELPHIA SECTION.

The May meeting of the Philadelphia Section, in the Franklin Institute, May 16, was addressed by Dr. Herbert E. Ives on "Some Home Experiments in Illumination from Large Light Sources," and Mr. C. A. Peterson on "The Design of Combination Fixtures." There was also an exhibition of the latest types of residential glassware.

The Section will have a June outing which will be a joint outing with the Philadelphia Section of the American Institute of Electrical Engineers on the grounds of the Philadelphia Electric Company Athletic Association, on

Saturday afternoon, June 7th. There will be a baseball game between members of the Illuminating Engineering Society and the American Institute of Electrical Engineers. Prof. Franklin of Lehigh University will give a lecture on "Baseball Curves." Supper will be served on the grounds

On June 20 the section will hold a short business meeting and dinner at the Engineers' Club instead of a regular meeting. There will be some short speeches but no paper.

PITTSBURGH SECTION.

A meeting of the Pittsburgh Section was held May 16. Mr. J. L. Minick of the Pennsylvania Railroad Company read a paper on "Passenger Car Lighting." The paper appears in this issue of the TRANSACTIONS.

For the June meeting Messrs. Ward Harrison and E. J. Edwards of the National Electric Lamp Association are preparing a paper on the lighting of the new office buildings of the National Electric Lamp Division of the General Electric Company, at Nela Park, Cleveland.

New Members.

The following applicants were elected members of the society at a meeting of the Council, May 9, 1913:

AMRINE, T. H.
General Electric Company, Harrison, N. J.

BERGMAN, RUDOLPH L.
Salesman, Benjamin Moore & Co., 231 Front Street, Brooklyn, N. Y.

BERNHARD, ALBERT H.
1979 Bedford Avenue, Brooklyn, N. Y.

BRYANT, JOHN MYRON
Asst. Professor of Electrical Engineering, University of Illinois, Urbana, Ill.

DAVIDSON, JOHN M.
Civil and Sanitary Engineer, American Sheet and Tin Plate Company, 1224 Frick Building, Pittsburgh, Pa.

EHRLICH, HOWARD
Associate Editor, *Electrical Review and Western Electrician*, 608 S. Dearborn Street, Chicago, Ill.

ELLIS, EDGAR J.
President United Electric Const. Company, 1727 Sansom Street, Philadelphia, Pa.

FRITH, ANDREW M.
Burnham-Frith Electric Company, MacDougall Avenue, Edmonton, Alta., Can.

FROELICH, J. M.
Arc Lighting Engineer, Duquesne Light Company, 435 Sixth Avenue, Pittsburgh, Pa.

GRAY, A. A.
Managing Editor, *Electrical Review and Western Electrician*, 608 S. Dearborn Street, Chicago, Ill.

GRONDAHL, L. O.
Instructor, Carnegie Institute of Technology, Pittsburgh, Pa.

HENDERSON, R. G.
District Manager, General Electric Company, 30 Church Street, New York, N. Y.

IVES, ARTHUR S.
Ives & Davidson, 84 William Street, New York, N. Y.

KAULKE, JOHANNES
Electrical Engineer, General Electric Company, Sussex and Fourth Streets, Harrison, N. J.

KELLEY, J. B.
Salesman, Frank H. Stewart Electric Company, 35 N. 7th Street, Philadelphia, Pa.

KELLY, CLARENCE B.
Chief Estimator, United Electric Const. Co., 1708 Sansom Street, Philadelphia, Pa.

LATTA, J. E.
Associate Editor, *Electrical Review,* 608 S. Dearborn Street, Chicago, Ill.

LANDERDALE, JESSE E.
Sales Engineer, National X-Ray Reflector Company, 235 West Jackson Boulevard, Chicago, Ill.

MASON, FRANK L.
Instructor, Dept. Electrical Engineering, Columbia University, New York, N. Y.

MAUSER, R. H.
Engineer's Assistant, Consolidated Gas Company, 124 East 15th Street, New York, N. Y.

MCNEIL, R. S.
General Electric Company, Harrison, N. J.

OTTO, WILLIAM G.
General Sales Manager, Walker Electric Company, 2338 Nobb Street, Philadelphia, Pa.

ROWLAND, ERNEST W.
Chief Bond Inspector, Public Service Railway, Newark, N. J.

RYPINSKI, M. C.
Manager Detail and Supply Dept., Westinghouse Electric and Mfg. Company, 165 Broadway, New York, N. Y.

TRUITT, THOMAS GIBB
Imperial Electric Company, 1022 Arch Street, Philadelphia, Pa.

WATKINS, HOWARD E.
Vice-President and Designer, The Enos & Watkins Co., 36 West 37th Street, New York, N. Y.

Sustaining Member.

The United Electric Light and Power Company, New York, was elected a sustaining member of the society at a meeting of the Council, May 9, 1913.

Joint Meeting I. E. S. and A. G. I.

The following announcement has been issued by a special committee of the society, which is arranging for a joint meeting with the American Gas Institute:

"A joint session of the American Gas Institute and the Illuminating Engineering Society, will be held during the third week in October at the annual meeting of the Institute in Richmond, Va. While it is true that a number of gas men are active and influential in the work of our society, still a regret is frequently expressed that gas men and gas companies generally, do not take a more active interest. The gas business is so intimately bound up with our purposes and objects that it seems unnecessary to dwell on the value of our society to that great industry.

Your committee believes that this joint meeting will furnish an excellent opportunity for the arousing and stimulation of such an interest. It urges on the membership of our society the importance of a large attendance at this joint meeting, and of an abundant discussion of the papers presented to it.

We are notified by the Committee on Papers that the following papers have been secured:

"Some phases of the Illumination of Interiors," by Preston S. Millar, Secretary, Electrical Testing Laboratories, New York, N. Y. A lecture-demonstration employing minature rooms to illustrate several well known types of

lighting installations, indicating their peculiarities and good and bad features.

"The Importance of Direction, Quality and Quantitative Distribution of Light in Illumination," by M. Luckiesh, assistant physicist, National Electric Lamp Association, Cleveland, Ohio, a lecture-demonstration chiefly by subjects taken from the fine arts.

"Gas Lighting of Interiors," by C. A. Luther, Illuminating Engineer, Peoples Gas Light and Coke Company, Chicago, Ill., a paper dealing with the lighting of interiors by gas, and illustrating the manner in which gas is used to obtain the results explained in Mr. Millar's demonstration.

"Street Lighting by Gas," by F. V. Westermaier, Engineer, Welsbach Street Lighting Company of America, Philadelphia, Pa., a paper dealing with street lighting from the standpoint of the most modern methods.

This will evidently be an entertaining and instructive session. The date of the joint meeting will be announced later.

1913 I. E. S. Convention.

The seventh annual convention of the Illuminating Engineering Society will be held in Pittsburgh, September 22 to 26 inclusive. A committee of which Mr. C. A. Littlefield, 55 Duane Street, New York, is chairman, is engaged in formulating plans for the biggest and most successful convention yet held by the society.

TRANSACTIONS

OF THE

Illuminating Engineering Society

MAY, 1913

PART II

Papers, Discussions and Reports

[MAY, 1913]

CONTENTS -- PART II

STREET LIGHTING OF GREATER NEW YORK.*

BY C. F. LACOMBE.

Synopsis: Included in the following paper is a description of the plan or system of street lighting of the City of New York. With its accompanying illustrations the paper presents a comprehensive outline of the progress which has been made, particularly within the past decade.

In appearing before you this evening in an endeavor to describe the street lighting of the City of New York and the efforts made to improve it, and to make it attractive and artistic, my attitude is not that of a Philistine, satisfied fully with the engineering and efficiency results attained. Nor is it my desire to impress that idea, for the results so far reached are not entirely satisfactory. More than that, however, the endeavor has been made within imposed limitations to make the lighting agreeable and artistic, and on this point it is hoped your interest and sympathies may be enlisted by the description of the work that is being done.

In order to make the situation clear, it is necessary to briefly describe the limitations under which one has to work in the city government. Like all artistic or utilitarian things, illumination is a matter of money to a certain degree. Since 1905, the legislature has limited, properly, the prices to be paid for illuminating units, and the Board of Estimate and Apportionment, in the budget, has limited from year to year the number of units of illumination that may be added by setting the amounts of money that can be used in each borough. There are further limitations in connection with opening streets, etc., which restrict the time of construction, particularly in Manhattan and Brooklyn, so that only a certain amount of physical work can be done each year. In consequence, progress in improving lighting is slow and conservative to avoid frequent changes, and should be so, particularly in the older sections of the city. None of you who know the illuminating art is willing to say the last improvement has been

* An address delivered before a joint meeting of the Municipal Art Society and the New York section of the Illuminating Engineering Society, February 21, 1913.

made, or that the last unit of illmuination has arrived. You also know how necessary it is not to jump at conclusions, or adopt new units without careful study and trial, and in this term, units, is included both the light source, its reflectors and diffusing media. From this you can see that we are limited to the use of standard tried lighting units and that new ones cannot be adopted without a working trial, for the reason that the illuminating service purchased by the city must not be lessened or impaired.

The city contracts with public service corporations to supply it with certain illumination and illumination service on its streets. That means that the illumination is to be given by certain proved lighting appliances, or, in other words, proved units, and that these appliances or units are to be kept in a condition giving as nearly as possible perfect operation. The term "perfect operation" is the definition of "good service." It depends on many elements and great attention to detail. In 1888, when first engaged in electrical work, a small handbook was given me which said "The best electric system is the man who runs it"—a crude way of saying the best illuminating system depends on the efforts of the men who run it. This was in the days when there were many different so-called systems of producing electricity for illumination work. Now, the efforts of the men who operate a lighting system largely determine whether the householder or the community get good or bad service, and the clumsy epigram quoted is just as true now as then.

Good service in electric and largely in gas lighting, depends on the active strength and reserve capacity of the central station and its relays, the perfection and reliability of the distribution system, the detailed care and attention given to the most reliable lighting appliances obtainable for the system, and last, but not least, the discipline, co-ordination and co-operation enforced between the above elements as established and maintained by the man in charge. This man and his loyal assistants may really be called the slaves of the lamp, and those of us who have been such slaves, know the strange fascination of this work and its demand for the sacrifice of all else to it. But that fascination and devotion mean good service, and successful lighting service can never be obtained

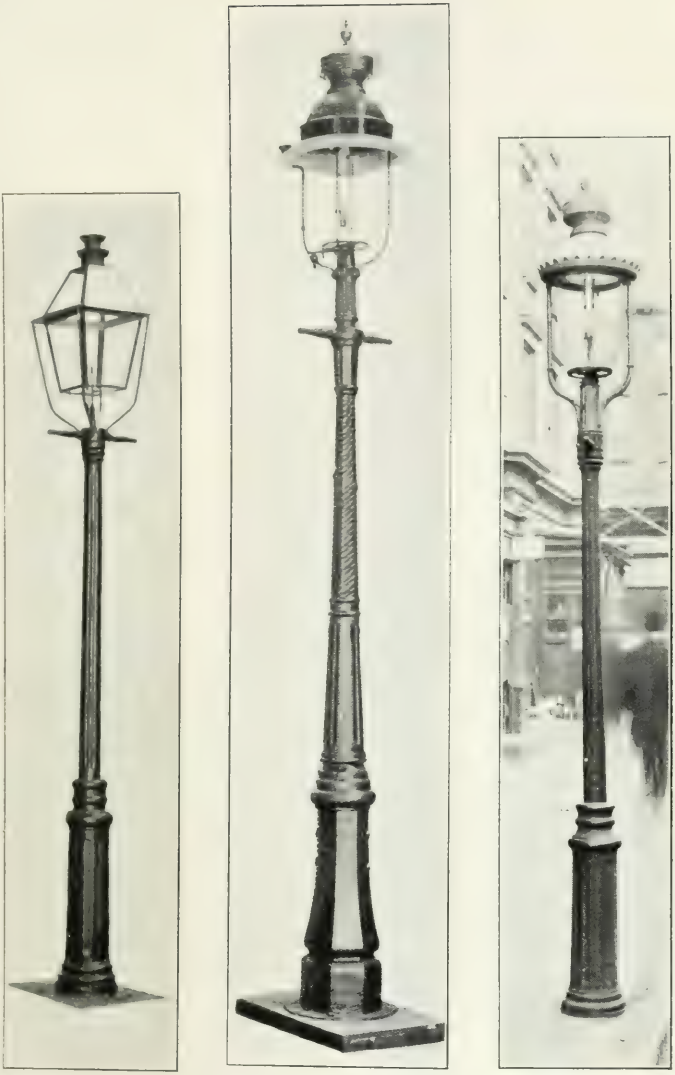

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Fig. 1.—Gas lamp posts: (a) Old gas iron type in use about fifty years. Designed for open gas flame of about 13 candle-power. Weight of lantern about 14 pounds. (b) Early mantle type, using lantern weighing 32 pounds. Average candle-power 35 to 40. (c) Present mantle type. Center of illumination is 9' 6" above the ground. Average candle-power 35 to 40.

a b c

Fig. 2.—Arc lamp posts: (a) Bishop's crook type. Design embodies suggestions of Stanford White. Lamps trimmed from post or by tower wagon, there being no lowering device. (b) Lyre top post, as used in center-parked plots on broad streets, such as upper Seventh avenue. (c) Mast arm post, used to avoid tree interference. Used at curb to overhang the street, in some cases in connection with the lyre top, as in upper Seventh avenue and upper Broadway.

without it; nor can steady, continuous illumination—without which any attempt towards agreeable or artistic lighting is futile—be obtained.

Assuming this to be obtained, then, let it be asked what choice is offered in the way of lighting appliances for service. It is apparent on a moment's thought, that such appliances must be well tried and standard. New appliances cannot be used on regular service. They must be given long service tests in by-ways and unimportant sections, often improved and re-tried until they become reliable and of real value. Of such available appliances to-day, there are the arc lamp of standard design for both classes of current supply, and for both multiple and series systems; the incandescent lamp, in various intensities, with carbon, metallized and metal filaments, for similar current supply and distribution systems; the mantle gas lamp with either vertical or inverted mantles, increasing the number of mantles for increasing illumination; and, naphtha-vapor mantle lamps, giving the same illuminating effect as vertical mantle gas lamps. In addition, but not available in all parts of the city, are the high candle-power arc lamps using a metallic electrode, with which much can be done. In Manhattan, where the greatest congestion exists, long burning white flaming arc lamps, which afford still higher illumination for general street lighting are now being tried. A limited number of these lamps are being installed on Broadway, above 47th street and on 7th avenue, above 34th street. This list of lamps, then, comprises the lighting units which must be used at present.

This city differs from others in that low and high tension electrical distribution are both used on an extensive scale. In Manhattan the lighting is all on low tension multiple circuits, both direct and alternating. In by far the larger part of Brooklyn and all the other boroughs the street lighting, with a few minor exceptions, is by means of high tension direct or alternating current series circuits.

Gas supply for mantle lighting is available throughout the greater city, except in a few remote sections. Naphtha-mantle lamps are still used for frontier lighting, where neither gas nor electricity is available. Gas lighting was formerly used in parks,

but is now being abandoned for obvious reasons, in favor of the tungsten incandescent lamps. Of these various lighting units, in the greater city, there are: 19,180 standard enclosed arc lamps, 17,991 incandescent lamps, 78 flaming lamps, permanent and on trial; 44,653 single mantle gas lamps, 28 inverted mantle gas lamps on trial, 1,816 naphtha-vapor lamps. In all there are 83,746 lamps furnished by 28 lighting companies. Expressed empirically, the lamps give a horizontal illumination approximately equal to fifteen million candles.

For the purpose of street illumination, these lamps are used in the following manner:

Enclosed arc lamps, reinforced by flaming arc lamps, are installed at points of great congestion, as at Times Square, Manhattan.

Arc lamps are used on main avenues and business streets, practically over their whole length in Manhattan, and as far as necessary in other boroughs, and then merged into tungsten incandescent electric or gas mantle lamps.

Gas lamps are generally used in the residence districts and on unimportant streets, little used at night, although of late, for many reasons, the tungsten lamp has made great inroads on this territory.

Ten years ago last month, when the engineering charge of the illumination of Manhattan and the Bronx was put in my hands, it was found to be inadequate, unsymmetrical and out of date; the arc lamps on the main avenues were insufficient and often spaced irregularly, too far apart and not in symmetry in line or in height, except where standard fixtures were employed. Open flame gas lamps were in the majority, with gas mantles and arc lamps often mixed in with them. In other words, there was little, if any, system of lighting.

As soon as possible, this was corrected. First, prices were materially reduced by continuous agitation, and second, a plan of lighting developed. All open flame gas lamps were discontinued. Arc lamps were practically doubled in number at street and avenue intersections and symmetrically arranged as often as possible on street house lines; so that the illumination was made as uniform as it could be with the funds allowed. Mantle gas

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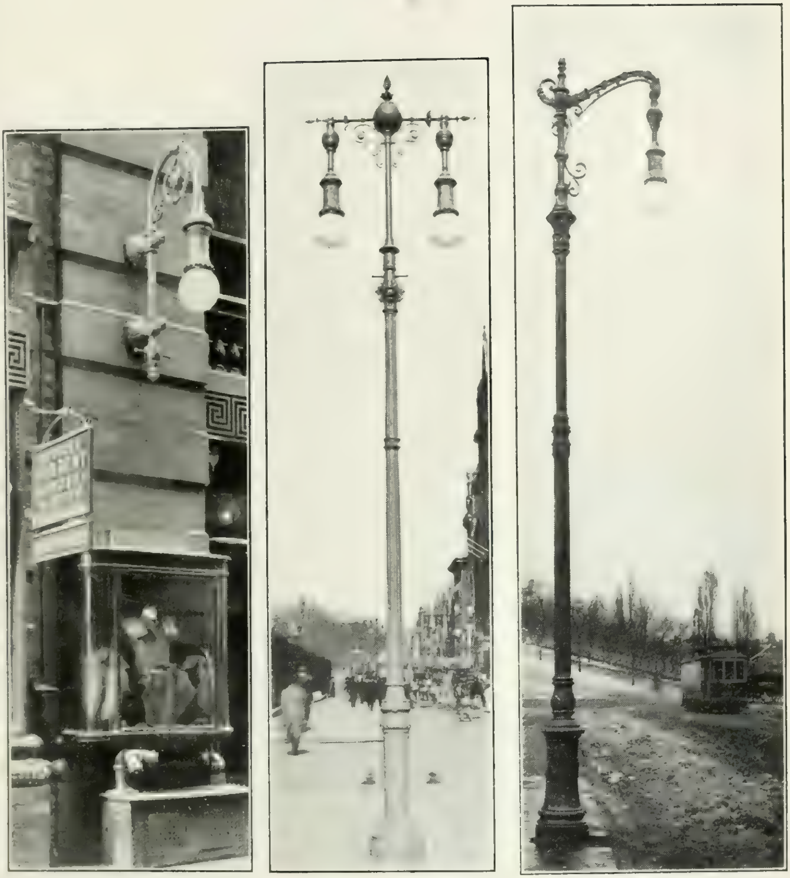

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Fig. 3.--(a) Bracket type; for use on buildings in narrow streets downtown, where a post would take up material width of limited sidewalk. (b) Twin lamp posts, as used in Fifth avenue. (c) Reverse scroll bracket post, as used on lower Seventh avenue and elsewhere; also used with flame arc lamps.

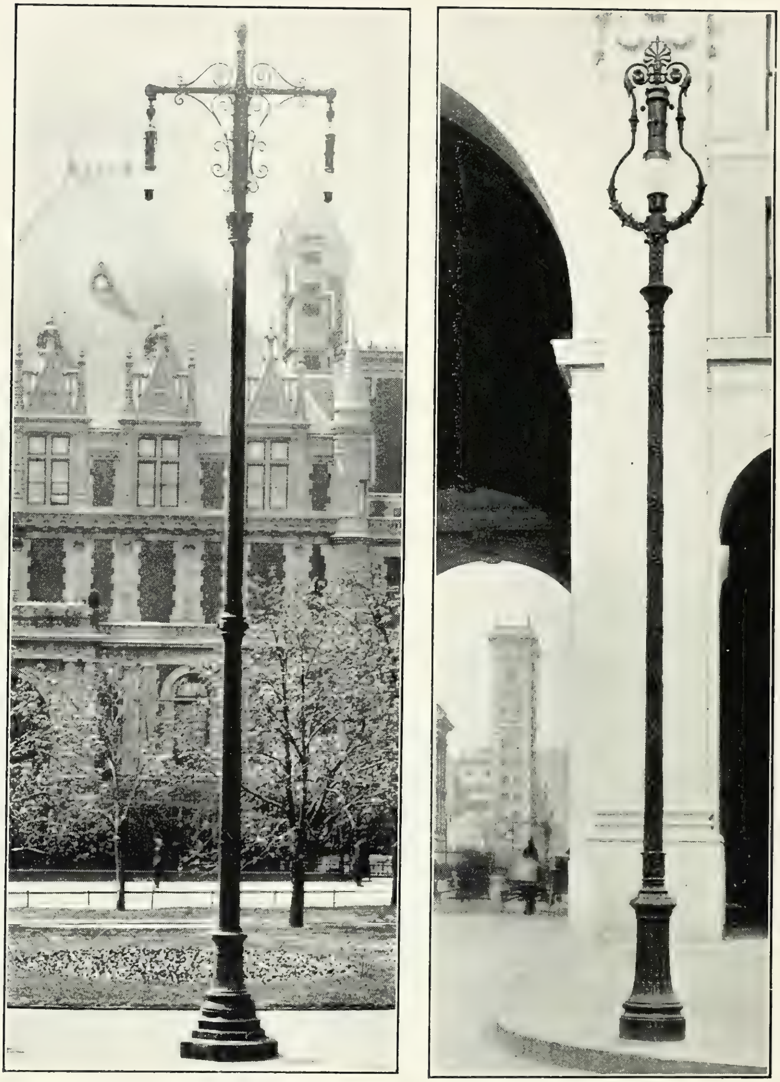

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Fig. 4.—Arc lamp posts: (a) High type ; used with powerful flame arc lamps in squares and open flames, as for example Times Square, Long Acre Square, etc.; height usually 45 feet, with globe of lamp about 39 feet from ground. (c) Ornamental pole, designed by McKim, Mead and White, for flame arc lamps used around new Municipal Building, Center and Chambers streets.

lamps were put on existing lamp posts in all residence streets excepting a few quarters where arc lamps were already installed. This arrangement as a whole has proved efficient and has been followed with improvements as they were worked out. The result may be seen in the enlarged system of uniform distribution of light sources in long straight parallel lines, exemplified best, first by Seventh avenue above Central Park and Fifth avenue from Washington Square to 60th street, and now by almost all the avenues in Manhattan, from west to east, running north to south, as well as on the main streets running east and west.

Late in 1905, the engineering charge of the illumination of the greater city was put in my care, as chief engineer, and early in 1906 such control was formally assumed. The same general system as used in Manhattan and the Bronx was put into effect in the other boroughs and the bureau organization in these boroughs made to conform to the simple system of development in illumination just described in Manhattan. It was modified in some ways, for in the outlying sections of Brooklyn and in Queens and Richmond the problem was quite different. In these boroughs it was the illumination of small towns and centres, with long connecting roads through truck farming districts from centre to centre. These districts are lighted by means of far flung alternating and direct current series systems of electrical distribution overhead on poles, with all the limitations of such suburban systems and companies. The same rule was worked out in symmetrical, continuous and uniform illumination with arc and tungsten lamps, and there are now established certain lines of well lighted roads from the City Hall in Manhattan, north to Yonkers, east to Nassau County, and central Long Island, as well as its north shore, southeast to Rockaway, south to Coney Island, and excepting the ferry, to the southernmost point of Staten Island. Cross and inter-connecting roads through country districts are also carefully illuminated. Other projects on this line are now building or planned, such as the Boston Road and Pelham Parkway and Park to Pelham and the south shore of Connecticut, another route via the Eastern Parkway, Brooklyn, to the Merrick Road and the south shore of Long Island.

This general system is now established on such basic lines that it can be developed consistently and without duplication of equipment expense using the present lighting units. Until congestion spreads from Manhattan, the lower portion of the Bronx and Brooklyn, to the outlying sections, to the extent that a considerable change from overhead line construction to underground subways becomes necessary, the development need only be to higher units and not a change in systems or equipment to any considerable extent.

A certain handicap will exist for some years in obtaining the best distribution of illumination in the suburbs on account of the overhead lighting lines and lighting being kept on one side of the street to avoid duplication of pole lines; but this, in time, will be removed.

In the congested area of Manhattan and in the Bronx, where underground distribution exists, the locations of the lamps on the main avenues are secured, and to realize the full perfection of the present plan, only higher sources of illumination are neded, and it is to that end the experiments with flaming arc lamps on Broadway and Seventh avenue are being made.

In this development care has been taken to avoid freak, or too accentuated lighting, on particular streets, as has been the case in some cities. The attempt has always been to keep to uniform, agreeable lighting, avoiding light sources of high intrinsic brilliancy and consequent glare. Where high intensity sources are used they are carefully diffused or kept out of the range of vision.

It is all a slow, but so far, sure progress of evolution, development and education. The results of the original plan of ten years ago now show in Manhattan, the Bronx and Richmond, and are beginning to show in the thoroughfares of Brooklyn and Queens. The mixture of lighting units has been generally removed or is in process of removal. In the last ten years, the illumination of the greater city, as specifically defined, has increased, under this system from seven million candles to fifteen million candles, or an increase of 118 per cent.

It is a peculiar and somewhat odd fact about all this development, that except in a few isolated instances, no one in this city seems to realize the improvement made in its lighting in later

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Fig. 5.—Tungsten lamp posts: (a) First ornamental type, French design; used in Central Park and on Riverside Drive. (b) Present ornamental type, designed by Henry Bacon for the Municipal Art Commission; used in park roadways. (c) Ornamental type with diffusing globe, designed by Bacon, used in special places in parks, for example, The Mall, Central Park. (d) City ornamental type, now used with 500-watt tungsten lamp, as shown, at Sherman Square, 59th street and Fifth avenue. See also Fig. 12.

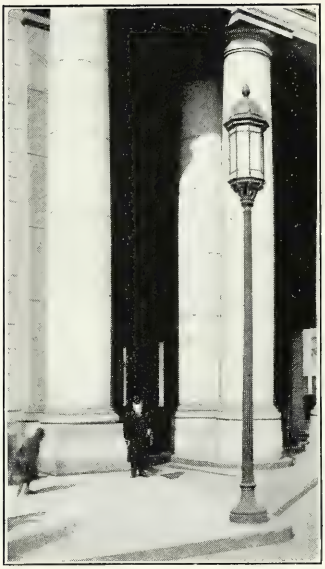

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Fig. 6.—(a) Municipal Art Society post; designed by Mr. Ciani and presented to the city by the Municipal Art Society. (b) Astor post; designed by Henrik Wallin and presented to the city by the Astor estate. Two located in front of the Astor Hotel, Broadway. (c) D. A. R. post; designed by Allen G. Newman and presented to the city by the Daughters of the American Revolution; to be placed at 72nd street and Riverside Drive. (d) Pennsylvania Station post; installed around the Pennsylvania Station and adjacent postoffice.

years. Few newspapers have ever mentioned it, and then but casually; no realization that a logical engineering scheme of development is taking place has been noticed, although it has been inherently correct enough to have been supported by the commissioners of four political administrations of the city government. It is only fair to say that the technical journals and societies have discussed it somewhat, and a number of other cities have noticed and studied the lighting and fixtures in use here with a view to their use in their own cities. In some cases our system has been adopted by them.

Even in this, a sort of peculiar pride is taken; for this city,

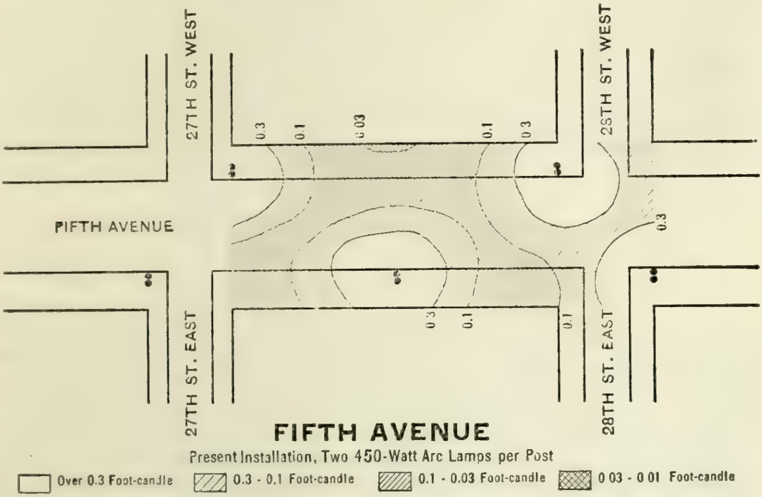

Fig. 7.—Diagram showing lamp locations and isointensity curves; two 450-watt enclosed arc lamps per pole; Fifth avenue; length of block 264 feet.

rushing on in its career to the goal of the greatest city of the world, has little time to do much but growl at real and fancied obstructions to its progress. In consequence, to keep up to the extension of the lighting demanded, the lighting bureau of the department has had little time to do anything but work, its efforts being devoted to making up for the lack of development in the past, and hurrying forward to meet the present demands of a greatly congested world centre. This is really the first address I have been able to make on this subject.

In a negative way, the work has been noticed; for example,

since the avenues have been doubled and tripled in illumination, we have heard a complaint that the side streets in Manhattan and the Bronx are dark, and such complaints are always listened to attentively, because they help the engineering scheme by impressing the political and financial powers that be. The side streets are comparatively dark, but in 1904, when the mantle gas lamps replaced the open flame gas lamps, these streets received more than three times the old illumination, so one can imagine what that illumination was. It may be truthfully said that were this city thrown back in a day to the lighting of ten years ago, the contrast would be so extreme there would be a riot, almost, on

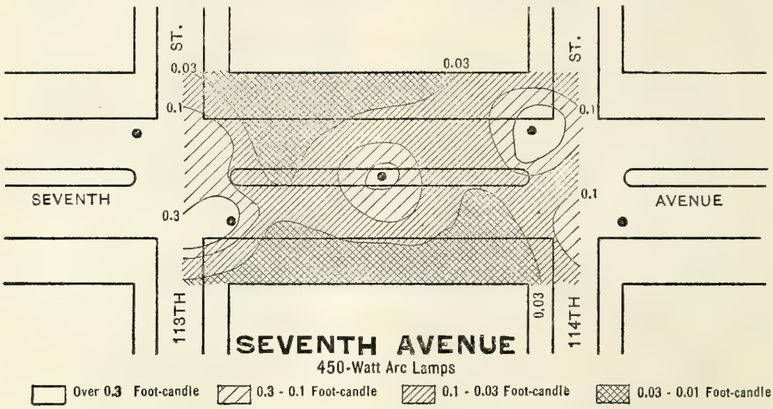

Fig. 8.—Diagram showing lamp locations and isointensity curves; mast arm and lyre top posts; 450-watt enclosed arc lamps; upper Seventh avenue; length of block 264 feet.

account of lack of illumination. In the elapsed time the increase has been slow, and, in consequence, not perceptible, except from year to year.

It is desired to emphasize the fact that under the engineering scheme all new lighting is carefully worked out mathematically and geometrically, on lines of proper illumination design. A temporary equipment is then erected, movable, if desired, and the final effect obtained by the actual trial and observation on the street. All suitable kinds of reflecting and diffusing devices and glassware are tried until the best result is reached. This example is then measured and plotted photometrically and checked, or corrected, as the case may be. Lighting is no longer installed empirically or by guess work.

Fig. 9.--Fifth avenue twin arc lamp posts (see Fig. 3); location shown in Fig. 7; night photograph.

Fig. 10.—Upper Seventh avenue; mast arm and lyre top posts (see Fig. 2); location as shown in Fig. 8; night photograph.

Fig. 11.—Broadway lighting with reverse scroll posts shown in Fig. 3; locations shown in Fig. 13; night photograph.

Fig. 12.—Plaza and Sherman monument, 59th street and Fifth avenue, illuminated by flaming arc lamps, enclosed arc and tungsten lamps, night photograph; tungsten lamps in the foreground and flaming arc lamps to the left beyond the range of the camera.

The newer lamp posts used for the improved lighting are also designed with great care. Even before the Municipal Art Commission took up this matter in a systematic and effective manner, as they did some years ago, the New York Edison Company had anticipated the demand for more attractive fixtures and has been, and still is pre-eminent in this regard.

It is well to state here, as one of the working conditions, that with few exceptions the arc lighting posts and fixtures belong to the companies throughout the greater city, the gas lamp posts all belong to the city, as do the tungsten lamp posts in the streets and

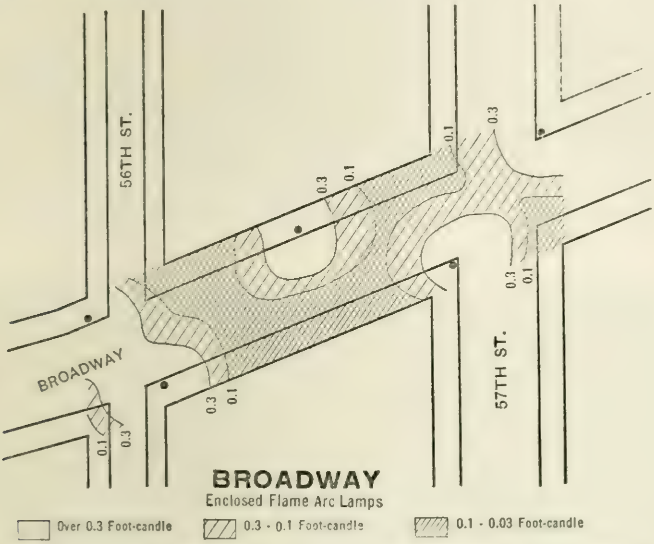

Fig. 13.—Diagram showing lamp locations and isointensity curves 450-watt enclosed flame arc lamps; Broadway.

parks on underground service. The lanterns and lamps themselves belong to the various companies. The posts now supplied by the lighting company are shown in the accompanying illustrations. They were first drawn, then life size plaster models made and revised, then the patterns developed and corrected until a satisfactory and harmonious result combining artistic effect with engineering construction was attained. These posts were then submitted to the Art Commission in every case and their criticisms embodied in the final result.

The city's posts also go through this process. In one case the Art Commission had designs drawn and paid for of both the lantern and posts for tungsten lamps for Central Park. This design has been used extensively throughout the city since and has been copied by other cities. The new posts for side street lighting will also be submitted to them, when funds are received, and it is hoped that the old ugly gas lamp post will shortly disappear from Manhattan.

It is natural that the attempt to make the lighting and fixtures artistic should begin, like the improved lighting system, in the borough of greatest congestion, where it is needed most, and where the lighting is required to be not only useful but strong, uniform and agreeable.

Manhattan is fortunate, in the engineering sense, in being supplied with its lighting service by a low tension multiple system, which is flexible and very adaptable to artistic effects with safety.

The lighting current is distributed by underground lines, and with energy supplied from the greatest electric generating station, gives the best obtainable service.

It has been my attempt so far to give you, as briefly as possible, the salient points of the conditions under which lighting work is done in this city. The endeavor has been made to be non-technical. It is necessary to remind you that the illustrations showing night lighting do not at all show the effect of the same lighting on the eye, so far as the source is concerned, so if you will compare the surfaces illuminated and not the source, you will have a more accurate comparison.

It is my pleasant duty to acknowledge how much I am indebted in accomplishing this work so far, first, to the support of the commissioners of the department; second, to the collaboration and assistance of the engineering and service side of The New York Edison Company, led by Vice-president Lieb, the dean of all central station men, and to Mr. Rhodes, in charge of the arc lighting department, who has more than done his half of the work with me in this development; third, acknowledgment is also due to my own men, particularly to the general inspector of street lighting, whose accuracy and great attention to detail have done much towards the genera result.

Fig. 14.—Central Park Mall; ornamental ball tungsten lamp posts (see Fig. 5) night photograph; 60 candle-power lamps.

Fig. 15 —Central Park road lighting; tungsten lamp posts; (see Fig. 5-b) night photograph; 60 candle-power lamps.

Fig. 16.—Side street illumination; experimental tungsten lamp posts; locations shown in Fig. 18; night photograph.

Fig. 17.—Public library; lighting from enclosed arc lamps on the opposite side of Fifth avenue; approximately 0.1 foot-candle on face of building; night photograph.

In addition to the progress made, it has also been attempted to show in this paper, in a limited way, some of the diversified problems of the engineer in the lighting of this great city. He must proportion the lighting to the needs of the various streets or sections, and to their importance, due to greater or less use. He must lay out a system capable of great increase without expensive change of equipment, or the contracting companies will object. He must lay it out on economical and efficient lines and obtain judicially fair prices within limits, or the city administration will object. He must try to eliminate glaring lighting, or the Illuminating Engineering Society will protest and he must make it agreeable and as artistic as possible or the Municipal Art Society and Commission will criticise.

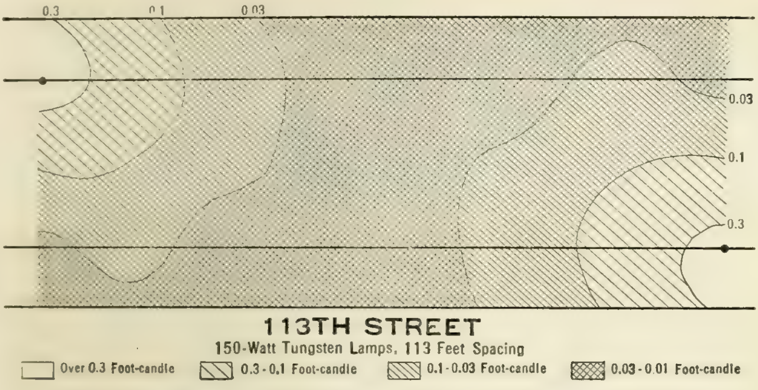

Fig. 18.—Lamp locations and isointensity curves new tungsten lamp posts for cross streets.

Agreeable and successful lighting is a combination of the efforts of all the different interests mentioned. It is not only a matter of artistic posts, but also artistic lighting, if I may use that term. To produce the best results, one must have the support of the city and the contracting company. The posts and the lighting must both be artistic and agreeable. The position, height and design of the supporting post have much to do with the effect of the distribution of the lighting, as well as its cost. It is in these latter details the artist and engineer can well work together. Within limitations, the artist must not demand too extremely, artistic a design in lighting; it is too costly except in a few isolated in-

stances. In the general lighting of a great city, the useful side must have as great weight as the artistic.

The engineer also should not cling too closely to the most efficient and economical devices which obtain only the greatest illumination, at the lowest cost, for the lighting must be made agreeable to the eye. In street lighting, unless surrounding buildings are to be specially illuminated, the useful rays are those that can be directed towards the ground. To make this agreeable, the point source of an arc lamp, for instance, must be made into a ball of softened light by diffusing globes or shades, and this, so far as is possible, thrown towards the ground by either interior or exterior reflectors. This practise reduces efficiency to a certain extent by the absorption of the light, and demands either closer spacing or more powerful sources of illumination at greater heights from the ground; it is, consequently, more expensive. So far, it has been used mainly in Manhattan and there, principally on its main avenues.

In other locations, one may see the naked source of the light which, in turn, means glare that is not as agreeable, although very useful and less expensive. Considerable success in suburban sections of the city has also been attained by abandoning the intense arc unit and using three to four 60-70 candle-power tungsten lamps, and so obtaining better distribution, with less glare, and at about the same cost.

There is nothing new in this plan of lighting. The ancient torch bearer always held his torch as high as possible to keep the glare out of one's eyes and to throw the rays over as great an area as possible. The engineer uses his new facilities for lighting in the same way, puts them as high as possible, and throws them over the greatest area he can. He only adds to the torch bearer's efforts, the diffusing globes and the downward reflectors.

Artists, too, can take advantage of the many possibilities of the new lighting devices, both in general and decorative illumination. Beautiful color schemes are possible with small colored lamps set in mosaic design, both massed and in outlines, on walls of buildings. As a substitute for advertising with glaring yellow flame lamps, the use of mosaic lighting would be vastly better and just as effective. Even general illumination, as given by the high

powered flame lamps can be tinted agreeably in contradistinction to dead, cold, white light. In other words, artistic lighting is as possible as any other form of art.

This address would lose its point if it failed in suggesting that the artist and engineer meet each other half way, and, by combination, produce a joint result, obtaining good, economical lighting, consistent with artistic standards. In this way, lighting can be designed which will command complete approval from all the points of view that may be invoked to judge it. If such combination is obtained, then I can say that five years of co-operation will make Manhattan Island first, and the greater city next, the best and most beautifully lighted city in the world.

DISCUSSION.

Mr. Clarence E. Clewell (communicated): The author has pointed out in a most interesting way that the progress in the lighting of New York has been made by keeping two main points in view, namely, first to avoid accentuated lighting in particular streets as has been the case in some cities on the one hand, and second, to secure uniform agreeable lighting on the other hand, thus avoiding light sources of high intrinsic brilliancy and the consequent glare. This policy is highly commendable and the results of an adherence to this safe principle are shown throughout the city.

An item of particular interest touched upon is the definition of good service, which is given as *perfect operation* of the lighting appliances. In securing perfect operation the author has aptly pointed out the necessity of not placing the entire burden on the lamp manufacturer, but states in a truism that "The best electric system is the man who runs it." The full meaning of this attitude is perhaps appreciated most by those who have been confronted with the operation side of lighting equipment, and a good lamp coupled with the care thus implied in its every day operation, is almost sure to result in satisfactory conditions for all concerned.

If in the criticism of improvements in city street lighting, due weight is placed on the necessity for moving slowly in the adoption of untried apparatus, such criticism will be far less unreas-

onable than otherwise. It is surprising, however, even with the conservatism this imposes, to note the many modern types of lamps which are either in regular service or on trial in this city. One thing which is nearly always noticed where lighting improvements have been effected, is the raising of the standard of illumination among even the unthinking. Thus the improvements in the lighting of the avenues, has lead to criticism of the side streets in Manhattan and the Bronx, and this in turn to improvements of the side streets. This feature is often a great help in extending higher and better illumination facilities.

The author has described the methods of engineering connected with the new schemes of lighting. It is a cause of much satisfaction to know that in the lighting of vast street areas, careful attention is being given the question of illumination design. Where the artistic side is naturally given so much weight, it would be an easy matter to place rather more emphasis on this feature than on the utility side.

The author has pointed out a principle of far reaching importance when he states that the useful side must have as great weight as the artistic, stating at the same time that it is equally important not to cling too closely to the highest efficiency of the units at the expense of an agreeable effect on the eye.

Throughout the whole address the author has shown that lighting, while not a new question, is made up of many items which are to-day looked at in new ways and which are solved by new methods.

This is the key-note in the progress of illumination at this time, and the fact that many of the items which concern the final excellence of any lighting system are often simple and even commonplace, should not under any circumstances lead us to overlook their great importance to the results obtainable.

Mr. J. W. Cowles (communicated): Mr. Lacombe sets forth most interestingly the good results to be accomplished by the adoption of a broad and systematic scheme for street lighting under the varying requirements which exist in every city, and the New York situation is a striking example of what can be accomplished by close co-operation between the many interests involved.

In many cities there may be seen street lighting apparently developed with the one idea of illumination or utility in mind, with practically no thought given to the artistic features, which are certainly of value even though secondary to practical utility. In other cases the reverse extremes are to be noted, but in New York there is a striking and pleasing balance between both the useful and the artistic.

I believe that much benefit can accrue to other municipalities and public utilities by careful consideration of the points emphasized in this paper.

ILLUMINATION OF PASSENGER CARS.*

BY J. L. MINICK.

Synopsis: This paper presents a brief record of the developments in the methods of passenger car lighting that have been witnessed since 1825 when the candle was the source of light employed. Various types of oil, gas and electric lamps which have been in general use are described and illustrated. Illumination readings and data obtained from cars lighted with lamps of the latter types are also included.

LIGHT SOURCES.

In their paper before the American Society of Mechanical Engineers last winter, Messrs. Wood and Currie divided the development of passenger car lighting into four twenty-five year periods, beginning with the candle period in 1825. Oil lamps came into general use about 1850 and gas about 1875. About 1900 electricity came into use as a means of lighting passenger cars in steam train service, though it had previously been used extensively in electric cars.

Information concerning the early use of candles is very meagre. It is known, however, that Thomas Dixon, the driver of the first passenger car, furnished his patrons with candles. He also furnished a rough board table in the center of the car for supporting the candles. The passengers were required to light the candles and tend their feeble flames. The board table later gave way to sockets attached to the walls, and these were superseded by fixtures having glass chimneys to protect the flame and a coil spring in the bottom of the socket to force the candle upward as it burned away, thus maintaining the flame at a predetermined position. This type of candle fixture is used extensively to-day as an emergency lamp in case of failure of the primary gas or electric system.

"Center-lamps," with one or more candles, came into use during the latter part of the candle period. Many labor saving conveniences were developed, as for instance, an adjustable top to hold the chimney in position without the aid of thumb screws,

* A paper read at a meeting of the Pittsburgh section of the Illuminating Engineering Society, May 16, 1913.

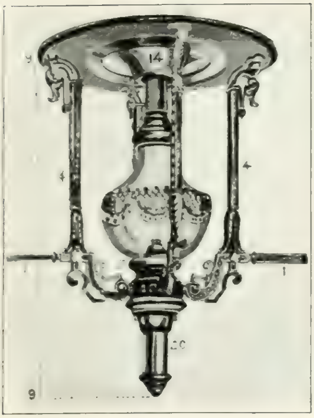

Fig. 1.—Center deck candle fixture. About 1840.

Fig. 2.—Center deck oil fixture. About 1860.

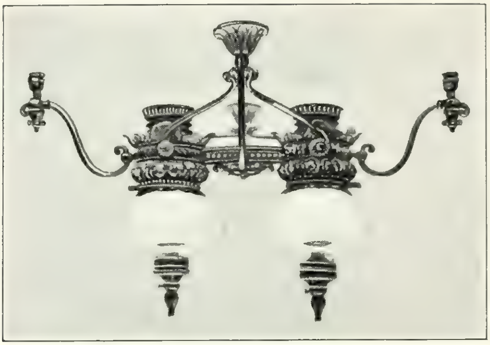

Fig. 3.—Center deck gas fixture. About 1880.

Fig. 4.—Center deck electric fixture. About 1906.

and brackets, that permitted of shifting the position of the lamp both vertically and horizontally.

While comparatively little has been written concerning the earlier types of oil lamps it is safe to assume that they resembled the candle lamp in general design. It was comparatively inexpensive and quite convenient to remodel the candle fixture to support an oil lamp. Such changes were very desirable as it is a very difficult matter in car work to patch a hole in the side or roof of a car without showing the patch.

Burners, wicks, etc., were adapted to the kind of oil used. The use of the heavier oils, such as rape seed and Colza vegetable oils, lead to the development of central draft burners, in which a current of air was delivered to both sides of the flame to produce more rapid combustion. The Argand, Belgian, acme and student lamps are representative types of central draft burners. Two wicks feeding one flame was another means of securing more rapid combustion, and consequently a brighter light.

Many of the oil fixtures were equipped with telescoping attachments for lowering the lamps for cleaning and filling. Others had removable oil reservoirs. Reflectors came into use during the oil period. In smoking cars, baggage and mail compartments cheap metal or mirror glass disks were placed back of the lamp to throw the light out into the car. In coaches conical opal glass shades were slipped over the chimney and were supported by the fixture arms.

Coal gas was probably the first kind of gas used in lighting railway cars. It was secured from the city gas mains and stored in a canvas reservoir, reinforced by wooden hoops, in the guards van. Iron pipes, and rubber hose between the cars, served to connect the lamps to the reservoir. Gasoline mixed with air was very extensively used. Acetylene gas was also used to some extent. Pintsch gas, invented in 1867, came into very general use on account of its reliability and increased storage capacity, obtained by charging at high pressure.

A variety of burners were used, the first of which was probably the flat or "fish tail" flame. There was also a central draft burner somewhat similar to the central draft oil burner. The substitution of mantles greatly improved the quality of the light.

For reasons previously explained the earlier types of fixtures resembled the oil fixture. Generally the fixtures, used prior to about 1905, were very ornamental in design to correspond with the interior finish of the car. The introduction of the steel car has changed this condition and present day fixtures have been greatly simplified.

While it had previously been used in electric cars, the incandescent lamp did not come into general use as a means of lighting passenger cars in steam train service until about 1900. Carbon, metallized carbon, tantalum and tungsten filaments were all used in about the order named, the latter type being in general use to-day. It was the high efficiency of the tungsten lamp that made electric car lighting possible, as the demand upon the battery for current was brought within the necessary limits of battery capacity and weight.

The earlier electric fixtures were generally gas fixtures remodeled to take incandescent lamps, many of which were not equipped with reflectors. Such reflectors as were used served as dust collectors, and by thus attracting attention, served to stimulate the cleaning of the car.

The wide dissemination of knowledge of illumination, and the constant and earnest study of the problems of serving the traveling public, has resulted in better fixture designs, better distribution of light, higher intensities, and higher efficiencies. Filigree work has almost entirely disappeared. Simplicity of design has very materially decreased initial costs and the use of reflectors specially adapted to car service has made it possible to conceal the incandescent filament without the use of opal dipped or frosted lamps. It should not be assumed, however, that the last word has been said on this subject. There is a wonderful field for further development and improvement.

ILLUMINATION.

While close attention is now being given to the proper lighting of passenger cars, the chief effort, until within comparatively recent years, was to reduce energy consumption and simplify methods of operation. Lack of attention to the proper shielding of the filaments, the better distribution of light, and the production of intensities sufficient for the comfort of passengers, was

largely due to lack of knowledge of this subject and lack of facilities for accurately determining the conditions that obtained. The development of the candle-foot photometer and other devices has made it possible to determine all of these items and wonderful improvements have been made in recent years.

The data herewith has been selected from a series of tests of oil, gas, and electrically lighted cars, conducted during the past three years. The cars were all taken from regular service and the results are therefore, representative of service conditions. While the dimensions of the cars, the spacing and height of fix-

CAR		FIXTURES		ILLUMINATION		FOOT-CANDLE READINGS					
Class	P. f	System	Oil	Test	Standing	1	.64	1a	.61	1w	.54
No	3218	Fixture	2 Lt Cen Deck	Reading Plane	36″	2	.60	2a	.56	2w	.50
Type	Wood	No Fixtures	4	Max. F C	.64	3	.64	3a	.52	3w	.42
Floor Area, Sq Ft.	367	Spacing	124″ x 115½″	Min. F. C.	.24	4	.64	4a	.61	4w	.56
FINISH		Height	95″	Aisle Av. F. C.	.55	5	.61	5a	.57	5w	.53
Upper Deck	Light Green	Reflector	Cl. Ch #4 L.Op.Dm. #104	" Seats Av. F. C.	.50	6	.53	6a	.45	6w	.35
Lower "	" "	Lamp	No. 3 Dual Burner	Window " " "	.44	7	.41	7a	.39	7w	.35
Above Belt	" Oak	Rating		Car Av F. C.	.48	8	.34	8a	.28	8w	.24
Below "	" "	Lumens per Lamp		Lumens Utilized	114						
Seats	Red Plush	Total Lumens		Efficiency							

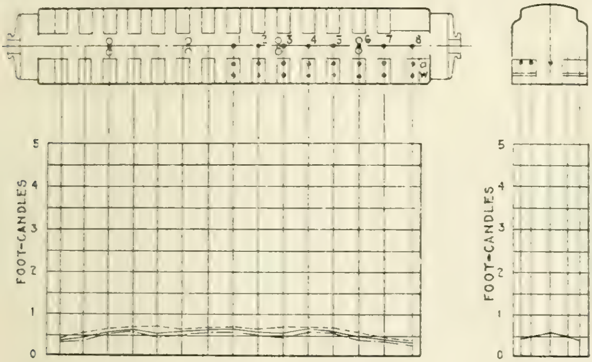

Fig. 5.—Two-light dual burner fixtures—standing.

tures, color of interior finish, etc., vary to a slight degree. the variations are not so great that comparison of the several types of equipment cannot be made.

No special attention was given to the cleaning of the cars other than to see that the lamps were cleaned and in proper adjustment. All tests were conducted at night and the blinds were drawn to prevent the leakage of outside light. When air draft and temperature conditions tended to affect the value of the illuminant, both standing and running tests were made. All

CAR		FIXTURES		ILLUMINATION		FOOT-CANDLE READINGS					
Class	Pf	System.	Oil.	Test.	Running.	1	1.34	1a.	1.27	1w.	1.15
No.	O V R.R. 3210	Fixture	2 Lt Center deck	Reading Plane.	.36"	2	1.29	2a	1.35	2w	1.20
Type	Wood	No Fixtures	4	Maximum F. C.	1.44	3	1.11	3a	1.14	3w	1.15
Floor Area Sq. Ft	400.	Spacing	126"	Minimum F. C.	.62	4	1.44	4a	1.39	4w	1.19
FINISH		Height	92"	Aisle av. F. C.	1.11	5	1.29	5a	1.25	5w	1.02
Upper Deck	Olive Green	Reflector Cl Chimney op dome		Aisle Seats F C	1.13	6	.86	6a	.96	6w	.92
Lower	" "	Lamp	Acme Burner	Window Seats av FC	1.01	7	.86	7a	.99	7W	.83
Above Belt	Light Oak	Rating		Car Av. F. C.	1.08	8	.66	8a	.71	8W	.62
Below	" "	Lumens per lamp		Lumens utilized	432						
Seats	Red Plush	Total lumens		Efficiency							

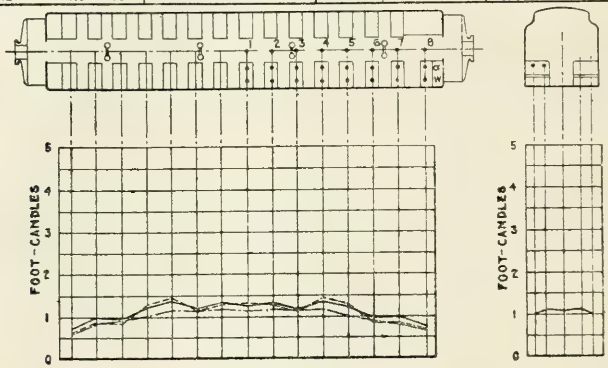

Fig. 6.—Two-light burner fixtures—running.

CAR		FIXTURES		ILLUMINATION		FOOT CANDLE READINGS.					
Glass.	Pf	System.	Oil	Test.	Standing	1	1.25	1a	1.11	1w	.96
No.	Q.V.R.R 3210	Fixture.	2Lt. Center Deck	Reading plane	36"	2	1.18	2a	1.20	2w	1.05
Type.	Wood	Number fixtures.	4	Maximum f c	1.35	3	.94	3a	1.06	3W	.99
Floor area sq. ft.	400	Spacing.	126"	Minimum f c	.60	4	1.35	4a	1.26	4w	1.08
Finish.		Height.	92"	Aisle av fc	1.05	5	1.23	5a	1.18	5w	.97
Upper deck.	Olive green	Reflector. Cl. chimney - op dome		Aisle seats av f c.	1.05	6	.85	6a	.89	6w	.85
Lower deck.	" "	Lamp.	Acme burner	Window seats av f c	.91	7	.93	7a	.94	7w	.79
Above belt.	Light Oak	Rating.		Car av. f. c.	.99	8	.68	8a	.72	8w	.60
Below belt.	" "	Lumens per lamp.		Lumens utilized	396						
Seats.	Red plush	Total lumens.		Efficiency.							

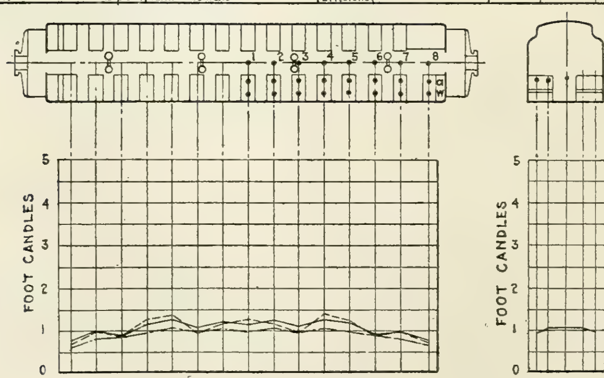

Fig. 7.—Two-light burner fixtures—standing.

CAR		FIXTURES		ILLUMINATION		FOOT-CANDLE READINGS					
Class	Pf.	System Carburetter Gasoline		Test	Running	1	1.46	1a	1.35	1w	1.08
No.	W.J.&S.R.R 3719	Fixture	1 Lt Center Deck	Reading Plane	36"	2	1.16	2a	1.04	2w	.90
Type	Wood	No Fixtures	5	Maximum Ft C	1.46	3	1.19	3a	1.12	3w	.91
Floor Area, Sq. Ft.	367	Spacing	80"	Minimum Ft C	.30	4	1.12	4a	1.03	4w	.91
FINISH		Height	90"	Aisle Av Ft C	1.09	5	1.44	5a	1.37	5w	1.03
Upper Deck	Olive Green	Reflector	Cl. Globe	Aisle Seats Av. Ft C	.99	6	.93	6a	.71	6w	.65
Lower "	" "	Lamp Inverted Argand Burner		Window Seats Av Ft.C.	.83	7	.30	7a	.30	7w	.30
Above Belt	Light Oak	Rating		Car Av Ft C	.94						
Below "	" "	Lumens per Lamp		Lumens utilized	.345						
Seats	Red Plush	Total Lumens		Efficiency							

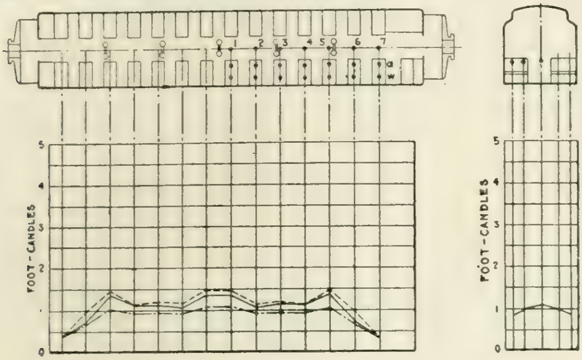

Fig. 8.—Inverted Argand burner—running.

CAR		FIXTURES		ILLUMINATION		FOOT-CANDLE READINGS					
Class	Pf	System Carburetter Gaselene		Test	Standing	1	1.34	1a	1.12	1w	.94
No	W J & S RR 3719	Fixtures	1 Lt Center deck	Reading plane	36"	2	.95	2a	.87	2w	.74
Type	Wood	No fixtures	5	Max f c	1.35	3	.74	3a	.70	3w	.65
Floor area sq ft	367	Spacing	80"	Min f c	.30	4	.87	4a	.76	4w	.69
Finish		Height	90"	Aisle av f.c	.90	5	1.35	5a	1.15	5w	.98
Upper deck	Olive green	Reflector	Cl. globe	Aisle seats av f c.	.80	6	.78	6a	.71	6w	.64
Lower deck	" "	Lamp inverted Argand burner		Window seats av f.c.	.71	7	.30	7a	.30	7w	.30
Above belt	Light Oak	Rating		Car av fc	.78						
Below belt	" "	Lumens per lamp		Lumens utilized	286						
Seats	Red plush	Total lumens.		Efficiency							

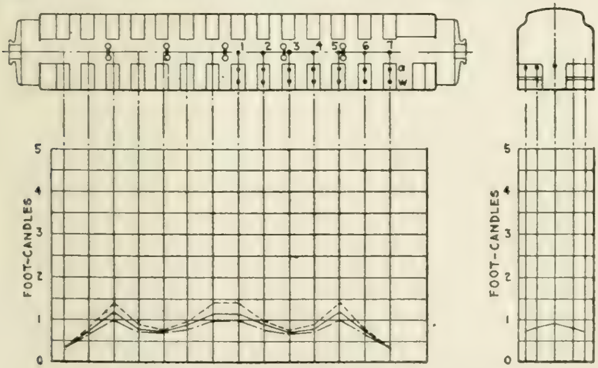

Fig. 9.—One-light inverted Argand burner—standing.

running tests were made while the cars were running at a uniform speed of about 40 miles per hour. So far as possible, all equipment was adjusted to operate at the manufacturers rating and where such adjustment was not possible proper correction has been allowed. In the case of running tests, lamps were adjusted for running conditions and no change in adjustment was made for standing tests. Foot-candle readings were taken on the horizontal plane 36 (0.914 m.) inches above the floor.

Figure 5 shows a standing test of dual burner oil lamps. This type of fixture consists of two lamps spaced on about 16-inch (40.64 cm.) centers cross-wise of the car. Each lamp has

CAR		FIXTURES		ILLUMINATION		FOOT-CANDLE READINGS					
Class	PK	System	Pintsch Gas	Test	Standing	1	1.02	1a	1.18	1w	1.02
No.	1175	Fixtures	2 Lt. Center Deck	Reading Plane	36"	2	1.15	2a	1.11	2w	.92
Type	Wood	No. Fixtures	5	Max. F. C.	1.18	3	1.07	3a	1.08	3w	.92
Floor Area, Sq. Ft.	392	Spacing	106½"	Min. "	.61	4	.85	4a	1.06	4w	.90
FINISH		Height	96"	Aisle Av. F. C.	.94	5	.99	5a	.96	5w	.83
Upper Deck:	Light Olive Green	Reflector	Cl. Gl. #126 Op. Dm. #127	" Seats Av. F. C.	.97	6	.99	6a	.91	6w	.73
Lower "	" " "	Lamp	Inv. Argand Burner	Window " " "	.84	7	.71	7a	.84	7w	.81
Above Belt	" Oak	Rating	27 m.s.c.p.	Car Av. F. C.	.81	8	.70	8a	.65	8w	.61
Below "	" "	Lumens per Lamp	339	Lumens Utilized	357						
Seats	Brown Plush	Total Lumens	1695	Efficiency	21.1%						

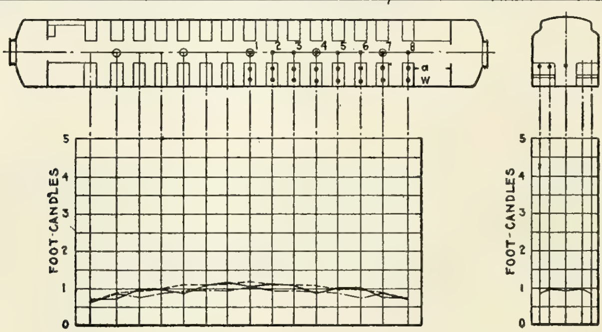

Fig. 10.—Two-light inverted Argand burner—standing.

two wicks feeding a single flame. Oil is fed through tubes from a common central reservoir. Each lamp was equipped with clear chimney and conical opal glass reflectors. Burners were adjusted so that the center line of the flame was at right angles to the axis of the car.

Figures 6 and 7 show running and standing tests respectively with Acme burner oil lamps. This is a central draft type of burner. Each lamp was equipped with a clear glass chimney and an opal reflector. The illumination was pleasing and sufficient for newspaper reading. The light interior finish added to the appearance of the car.

CAR		FIXTURES		ILLUMINATION		FOOT-CANDLE READINGS					
Class	Pk	System	Pintsch Gas	Test	Running	1	2.93	1a	2.66	1w	1.78
No	3409	Fixtures	1 Lt Center Deck	Reading Plane	36"	2	2.21	2a	1.92	2w	1.67
Type	Wood	No Fixtures	5	Maximum F C	2.93	3	2.22	3a	2.21	3w	1.76
Floor Area, Sq ft	392	Spacing	106½	Minimum F C.	1.11	4	2.89	4a	2.48	4w	1.73
FINISH.		Height.	96"	Aisle av. F C.	2.32	5	2.19	5a	2.05	5w	1.71
Upper Deck	Pea Green	Reflector	Frosted Globe #3055	Aisle Seats av F C.	2.08	6	2.09	6a	1.76	6w	1.54
Lower "	"	Lamp	Large mantle #3044	Window Seats av F C	1.60	7	2.74	7a	2.25	7w	1.46
Above Belt	Light Oak	Rating	48.5 m.o.c.p	Car av F C	1.83	8	1.29	8a	1.29	8w	1.11
Below "	"	Lumens per lamp	609	Lumens utilized	757						
Seats	Brown Plush	Total Lumens	3045	Efficiency	24.9%						

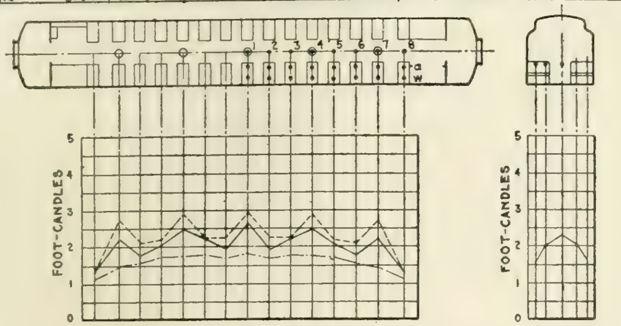

Fig. 11.—One-light single mantle—running.

CAR		FIXTURES		ILLUMINATION		FOOT-CANDLE READINGS					
Class	Pk	System	Pintsch Gas	Test	Standing	1	[illegible]	1a	2.98	1w	1.98
No PRR	3409	Fixtures	1 Lt Center deck	Reading plane	36"	2	2.20	2a	2.17	2w	1.85
Type	Wood	No Fixtures	5	Maximum f c	2.98	3	2.25	3a	2.10	3w	1.87
Floor area sq ft	392	Spacing	106½	" " "	1.22	4	2.81	4a	2.53	4w	[illegible]
Finish		Height	95"	Aisle av fc	2.28	5	2.13	5a	2.18	5w	[illegible]
Upper deck	Pea green	Reflector	Frosted Globe 3055	Aisle seats av f c	2.22	6	1.99	6a	1.98	6w	1.65
Lower deck	" "	Lamp	Large Mantle 3044	Window seats av fc	1.74	7	2.63	7a	2.46	7w	1.56
Above belt	Light Oak	Rating	48.5 M S c p	Car av fc	2.04	8	1.32	8a	1.39	8w	1.22
Below belt	" "	Lumens per Lamp	609	Lumens utilized	800						
Seats	Brown Plush	Total lumens	3045	Efficiency	.263%						

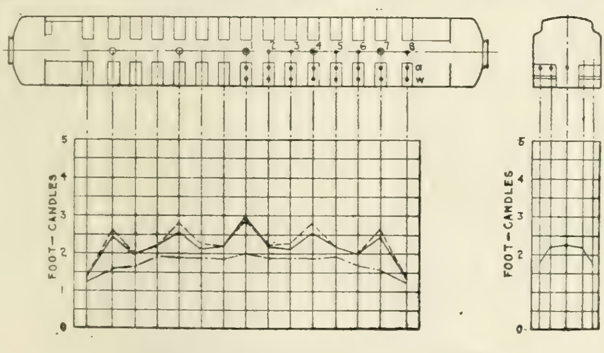

Fig. 12—One-light single mantle—standing.

CAR		FIXTURES		ILLUMINATION		FOOT-CANDLE READINGS					
Class	P-70	System	Electric	Test	Standing	1	2.67	1a	2.55	1w	1.76
No.	1819	Fixture	1 Lt. Center Deck	Reading Plane	36"	2	2.82	2a	2.75	2w	1.76
Type	Steel	No Fixtures	10	Max. F.C.	2.95	3	2.75	3a	2.43	3w	1.64
Floor Area Sq. Ft.	538	Spacing		Min. "	1.25	4	2.66	4a	2.40	4w	1.66
FINISH		Height	98"	Aisle av F.C.	2.64	5	2.76	5a	2.53	5w	1.72
Upper Deck	Apple Green	Reflector	S_1 Prismatic	Aisle Seats av F.C.	2.38	6	2.95	6a	2.57	6w	1.75
Lower "	" "	Lamp	50 W 60 V. Tungsten	Window " " "	1.62	7	2.88	7a	2.37	7w	1.67
Above Belt	Ungrained Light Oak	Rating	40 c.p.	Car av. F.C.	2.13	8	2.62	8a	2.31	8w	1.59
Below "	Dark Green	Lumens per lamp	409	Lumens utilized	1146	9	2.49	9a	2.25	9w	1.41
Seats	Green Plush	Total Lumens	4090	Efficiency	28.0	10	1.81	10a	1.56	10w	1.25

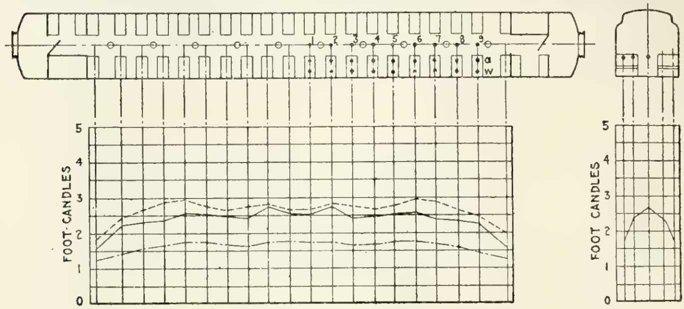

Fig. 13.—One-light electric fixture—standing.

CAR		FIXTURES		ILLUMINATION		FOOT CANDLE READINGS					
Class	P-70	System	Electric	Test	Standing	1	3.86	1a	3.43	1w	2.41
No.		Fixture	1 Lt. Center Deck	Reading plane	36	2	3.73	2a	3.42	2w	2.53
Type	Steel	No. Fixtures	10	Max f-c	3.86	3	3.69	3a	3.30	3w	2.36
Floor Area, Sq. Ft.	538	Spacing		Min. f-c.	2.21	4	3.72	4a	3.39	4w	2.49
FINISH		Height		Aisle av. f-c.	3.57	5	3.45	5a	3.18	5w	2.39
Upper Deck	Apple Green	Reflector	18226 S F	Aisle seats av f-c	3.26	6	3.35	6a	3.16	6w	2.33
Lower "	" "	Lamp	50w-60v Tungsten	Window seats av f-c	2.41	7	3.47	7a	3.26	7w	2.40
Above Belt	Ungrained Lt Oak	Rating	40 c p	Car av. f-c	3.07	8	3.43	8a	3.22	8w	2.45
Below "	Dark Green	Lumens per lamp	409	Lumens utilized	1652	9	3.32	9a	2.96	9w	2.21
Seats	Green Plush	Total lumens	4090	Efficiency	40.4%						

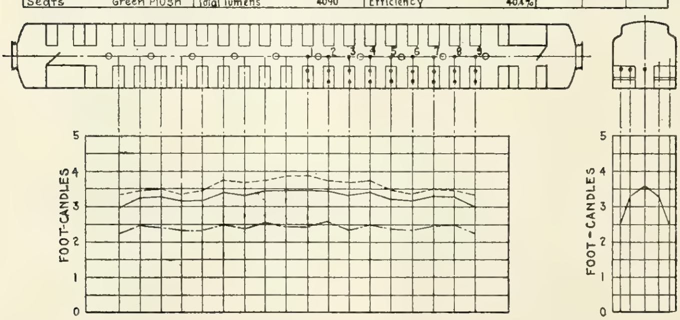

Fig. 14.—One-light electric fixture—standing.

Figures 8 and 9 show running and standing tests respectively of central draft types of carburetted gasoline equipment. The burner is inverted in a clear glass bowl. Air from the train system is passed through a spiral tube containing a wick soaked in gasoline, and the resultant mixture passes to the lamp to be burned. The carburetter is placed on the top of the car above the lamp so that the heat of the air raising from the lamp will heat the incoming gas. This type of lamp is very susceptible to changes of temperature and draft, and therefore requires constant attention to prevent smoking, especially during stops at stations.

Figure 10 shows the results obtained by the use of Pintsch gas with inverted Argand burner lamps.

Figures 11 and 12 show running and standing tests respectively of single mantle Pintsch gas lamps. Gas is carried in tanks under the car at a pressure of about 150 to 160 pounds per square inch (6.45 sq. cm.) and is reduced at the lamp to about two pounds per square inch (6.45 sq. cm.) With temperatures below 20 deg. F., some of the hydro-carbons are precipitated with a consequent reduction in illumination. It will be noted that there is practically no difference in illumination between running and standing conditions.

Figures 13 and 14 show the illumination that was obtained in steel cars equipped with 50-watt, 60-volt tungsten filament lamps, the first with flat prismatic reflectors and opal dipped lamps and the latter with satin finish prismatic bowl type reflectors with clear lamps.

CONCLUSIONS.

From these tests some idea of the comparative values of the several types of car lighting units may be had. Similar tests of cars varying only in interior color and finish will show changes in efficiency of 100 per cent. or more, and other tests of direct, semi-indirect and indirect fixtures will show considerable variation in current consumption. The standard car lighting battery is none too large from a capacity stand-point, while from a weight standpoint it is now as large as it can be made for convenience in handling. Changes in lamp efficiencies will be of little value until

they can be increased sufficiently to either reduce the weight or increase the hours of battery service from 25 to 50 per cent. Fixtures, reflectors and color of interior finish should receive further attention with a view of reducing maintenance and operating costs and providing better distribution of light at higher efficiencies. Comparative tests should be made with side light semi-indirect and indirect fixtures to determine their value not only from a standpoint of illumination, but from the more important stand-point of current consumption.

DISCUSSION.

MR. P. S. MILLAR: I have enjoyed Mr. Minick's talk very much. His sketch of the history of the development of railway cars is very interesting, while that part of it which pertains to car lighting, and which is included in the printed paper, sets forth a record of the improvement in this phase of illumination which heretofore has been lacking in our TRANSACTIONS.

In intensity of illumination the following is recorded in the way of improvement:

Oil—flat wick	0.57	foot-candle
Oil—center draft; gasoline and Pintsch gas	0.86 to 1.04	"
Pintsch mantle	1.99	"
Electric	2.60	"

But it is not alone in intensity that improvement has been effected. The illustrations show that in the latest installations with electric lamps, the filaments are shielded from ordinary view and depolished reflectors are used. These installations show the result of attention to car lighting which is very gratifying to all of us who have to use the trains and who have in the past suffered not only from inadequate lighting but also from bad lighting.

Recently I made a hurried trip from New ork to Boston and return. My seat was in a car illuminated by a large number of small tantalum lamps. The decoration of the car was dark so that not only the ordinary glare from the lamps led to discomfort, but this was enhanced by the great contrast of the lamps against the dark background. On the return journey I was accompanied by a member of this Society who is prejudiced against indirect lighting. It happened that we traveled in one of the new trains on the New Haven road, which is equipped

throughout with indirect lighting fixtures. After a casual observation, my companion commented adversely upon the illumination, speaking of inadequacy of light, cheerless appearance, etc. After five hours in the train, however, both of us were ready to say that, ocularly speaking, we had never had a more comfortable railway journey. The single feature of concealed light sources which characterizes indirect lighting was a most pleasurable element of lighting of a class in which exposure of light sources is all too often the most prominent feature.

All things taken into consideration, I think we may well feel gratified at the improvements in car lighting which are being effected by the leading railroads, of which the installation just referred to is one example.

Mr. A. C. Cotton: There are three general methods that are or have been in use to produce energy for illuminating electrically lighted cars. The first method was by the use of a straight storage battery which had its difficulties on account of the lamps sometimes being put on the battery while it was being charged, the lamps thus receiving a much higher voltage with a consequent shortening of the life of the lamps. When, therefore, the voltage dropped off to 1.8 volts per cell, the illumination was rather poor. Another method was by the use of a generator driven by a steam engine or turbine placed in the baggage car next to the locomotive, steam being furnished to these units through a hose connection from the locomotive. In some cases the turbine was placed directly on the locomotive. At times when there was a failure of steam on the locomotive, the engineer either throttled the steam to the generator unit, or turned it off altogether, which caused a failure of the electric lights on the entire train. One great trouble with this system was that in the event of the necessity of taking any one of the electrically equipped cars from the train, and substituting therefor either an oil or gas lighted car, all electrical lighted cars back of this car were in darkness. This caused considerable discomfort to the passengers and the railroad companies were severely criticised. On account of this and other difficulties, the head-end systems, whereby the cars were illuminated from a common train-line without the use of storage batteries, have been quite generally discarded.

The system quite generally used to-day is that known as the axle generator type, wherein each car is equipped with a generator suspended from the truck beneath the car, and driven by a pulley fastened to one of the axles. Each car is also equipped with a storage battery, generator regulator, for controlling the generator, and a lamp regulator, for controlling the voltage of the lamps. There are several different types of axle generator systems in use to-day, both foreign and domestic, but the ones we are principally interested in, are those manufactured in this country, as the foreign types have gained very slight foothold up to the present time. The generator in this system is equipped with a pole-changer, so that the polarity of the wiring is always the same, irrespective of the direction of the movement of the train. The generator regulator governs the point at which the generator is thrown in on the battery and also governs the output of the generator by changing the strength of the field of the same. The lamp regulator, which may be either motor operated or magnetically operated, acts so as to keep the voltage of the lamps constant, irrespective of the voltage of the generator or battery. By means of this system, the storage batteries on the cars are automatically charged while the train is in motion, the generator supplying current to either the battery or lamps, or both, while, when the train is standing, the current is supplied to the lamps from the battery.

Mr. J. L. Minick (In reply): The use of electricity, as a means of lighting passenger cars on the Pennsylvania Railroad, was brought about largely by reason of the improvements in the vicinity of New York City. On account of the large amount of trackage in tunnels under the North and East Rivers and Manhattan Island, it was thought wise to use only such equipment as contained no inflammable materials of any kind, consequently electricity became the agent for supplying light. As practically all of the steel equipment is likely to enter New York, electric light has become the prevailing system.

The length of run on a single battery charge, will of course, depend upon the demand for energy during the run. The batteries on the cars of the Pennsylvania Railroad have a rated capacity of 300 ampere-hours. Some of the express cars have a maximum current demand as low as 2.4 amperes, while certain

dining cars may exceed 45 amperes. So that the length of run may vary from 125 hours to about 6.5 hours of lighting. Coaches with 63-volt equipment have a current demand of about 10 amperes. Coaches have been run from New York City to St. Louis on one charge. I am not prepared to give the length of run possible on a full gas charge.

Referring to Mr. Millar's remarks, I wish to say that from the standpoint of illumination alone, I am very favorably inclined towards some form of indirect lighting. In car work, however, there are many considerations in addition to that of proper illumination. Standards have been fixed at an average intensity of three foot-candles for coaches and about five foot-candles for dining cars. The size and weight of the present 300 ampere-hour battery is as great as it can possibly be made for convenience in handling, while from a current capacity standpoint it is none too large. If semi-indirect lighting be used the current demand will probably be increased by 100 per cent. for the same intensity and if totally indirect be used it may be increased by several hundred per cent. If it be attempted to maintain equal brilliancy in the car the current demand will again be increased several times. Under present conditions I do not believe it possible to provide either semi-indirect or totally indirect lighting at a reasonable demand for energy.

When berth lamps were first used they were a decided improvement over the then existing conditions. I understand that an effort is now being made to entirely conceal the lamp but the space available in existing cars is probably so limited that changes for the better cannot be made conveniently. In the lighting of trolley cars it is necessary to place several lamps in series across the circuit on account of the high voltage used. As the failure of any lamp in this series puts the entire series out of commission it is necessary to provide several series circuits for a single car. In a small car this means a large number of small lamps. If the total number of lamps could be reduced I have no doubt more consideration would be given to correct lighting.

Mr. L. C. Porter: There are two sentences on the seventh page of Mr. Minick's paper, to which I would like to call attention. They are as follows: "The illumination was pleasing and

sufficient for newspaper reading. The light interior finish added to the appearance of the car." It seems to me that there should be a great deal more attention paid to the esthetic effects of the interior finish of cars, than is at present. If a car is finished entirely in dark color, no amount of light will make it appear bright and cheerful.

Photometer tests, while useful in comparing the actual efficiency of utilization of different systems, do not tell the complete story, and should be supplemented by personal observation.

Mr. Minick has asked for a discussion of the plane on which illumination measurements should be made in railway cars, calling attention to the fact that some people are making them on a 45 deg. plane, which is the plane in which a reader would naturally hold a paper, while others are making them on the horizontal plane. I believe both planes should be used. It is necessary to find the average illumination on the horizontal plane, in order to calculate the effective lumens and thus determine the efficiency of utilization of the lighting system, interior finish of the car, etc. Measuring on the horizontal plane, however, will not take into account shadow effects.

With high-power units and wide spacing, a passenger at the end of the car, seated with the first illuminant a considerable distance in back of him, might receive good light on his paper, while on the other hand, if he were facing the lighting unit, the side of the paper towards him would be in shadow.

I believe that at each station readings should be taken on three planes, namely, the horizontal, the 45 deg. towards one end of the car, and the 45 deg. plane towards the other. Multiplying the horizontal reading by the ratio of the two 45 deg. planes, always dividing the low reading by the high, will give a figure which will show more nearly the effectiveness of the illumination. For example, suppose the intensities on these three planes with two different lighting systems were as follows:

	Foot-candles Horizontal plane	Foot-candles 45 deg. rear	Foot-candles 45 deg. front
System A	3	3.20	2.56
System B	3	3.20	1.60

Then from system A we have $3 \times \frac{2.56}{3.20} = 2.4$, and from B we get $3 \times \frac{1.60}{3.20} = 1.5$. Clearly system A is the better system.

TRANSACTIONS
OF THE
Illuminating Engineering Society

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GENERAL OFFICES: 29 WEST THIRTY-NINTH STREET, NEW YORK

VOL. VIII JUNE, 1913 NO. 6

Council Notes.

A regular meeting of the Council was held in the general offices of the society, 29 West 39th Street, New York, June 13, 1913. Those present were: Preston S. Millar, president; Charles O. Bond, George S. Barrows, L. B. Marks, Norman Macbeth, Joseph D. Israel, general secretary, W. J. Serrill and George H. Stickney by an invitation.

A monthly report on the finances and membership of the society was received from the general secretary.

Upon recommendation of the Finance Committee, bills aggregating $1,833.99 were authorized paid.

Twelve applications for membership and four resignations were accepted. Counting these changes, the membership was said to total 1,373 members.

Reports of progress were received from the following committees: Reciprocal Relations with Other Societies, Collegiate Education, Advertising, Nomenclature and Standards, Progress, Research and Glare.

A report was received from the Committee on Tellers giving the results of the election of officers for the society and the several sections. The names of the officers elected appear elsewhere in this issue.

A report of progress on the work of the Philadelphia Section was received from Vice-President W. J. Serrill.

Two applicants, The Consolidated Gas, Electric Light & Power Company of Baltimore and the Welsbach Company, were elected sustaining members.

Additional appointments by the president to various committees were approved.

The general secretary was directed to prepare a report on the work of the Council during the present year to be submitted to the membership of the society.

The Executive Committee was empowered to act for the Council during the summer months.

A communication from the Heights of Buildings Committee of the City of New York inviting the society to cooperate with the committee in its work was read. The president was directed to acknowledge the communication and to state that the society will be glad to co-operate with the committee as far as possible.

New Members.

The following applicants were elected members of the society at a meeting of the Council, June 13, 1913:

BUTLER, HENRY EMANUEL
Asst. in Illuminating Engineering Laboratory, General Electric Company, Schenectady, N. Y.

ENGLISH, J. C.
President, J. C. English Company, 128 Park Street, Portland, Oregon.

FREEMEN, E. H.
Professor of Electrical Engineering, Armour Institute of Technology, 33rd Street & Armour Avenue, Chicago, Ill.

JOHNSON, OTIS L.
Illuminating Engineer, Benjamin Electric Mfg. Company, 120 So. Sangamon Street, Chicago, Ill.

KLINGMAN, A. M.
Asst. Commercial Engineer, National Quality Lamp Division of General Electric Company, Nela Park, Cleveland, O.

LANGAN, JOSEPH
Assistant Secretary, Illuminating Engineering Society, 29 West 39th Street, New York, N. Y.

ROLAND, E. U.
Headlight Field Man, Remy Electric Company, Anderson, Ind.

SCHOTT, ALBERT
Electrician, McCreery & Company, 6th Avenue & Wood Street, Pittsburgh, Pa.

SIMPSON, RICHARD E.
Asst. in Illuminating Engineering Laboratory, General Electric Company, Schenectady, N. Y.

STRANG, PERRY S.
Inspector, National X-Ray Reflector Company, 1119 West Jackson Boulevard, Chicago, Ill.

WANGERSHEIM, E. A.
President, General Lighting Fixture Company, 28 West Lake Street, Chicago, Ill.

WOOD, DOUGLASS
Illuminating Engineer, Bryan-Marsh Electric Works, 431 So. Dearborn Street, Chicago, Ill.

Sustaining Members.

At a meeting of the Council, June 13, 1913, the Consolidated Gas, Electric Light and Power Company of Baltimore and the Welsbach Company were elected sustaining members of the society.

Section Notes.

CHICAGO SECTION.

At a meeting of the Chicago Section in the Auditorium of the Western Society of Engineers, June 27, Mr. Arthur J. Sweet presented a paper entitled "Notes on Postal Car Illumination."

The following officers have been elected for the year beginning October 1, 1913: chairman, Dr. M. G. Lloyd; secretary, J. B. Jackson; managers, J. W. Pfeifer, Dr. Nelson M. Black, C. C. Schiller, M. J. Sturm and H. B. Wheeler. Mr. Jackson was re-elected secretary.

NEW ENGLAND SECTION.

The following officers have been elected for the ensuing year: chairman, C. A. B. Halvorson, Jr.; secretary, H. Harold Higbie; managers, R. B. Hussey, H. C. Jones, J. M. Riley, R. C. Ware and W. E. Wickenden. Since the election, Prof. Higbie has removed from the territory of the New England and has tendered his resignation as secretary. A secretary will be appointed by the new section board.

NEW YORK SECTION.

The following officers have been elected for the ensuing year: chairman, W. Cullen Morris; secretary, Clarence L. Law; managers, H. B. Rogers, C. R. Clifford, H. V. Allen, W. H. Spencer and Oscar Fogg. Mr. Law was re-elected secretary.

PHILADELPHIA SECTION.

The Philadelphia Section held a dinner at the Engineers' Club, 1317 Spruce Street, Friday evening, June 20. The dinner was held in place of the regular June meeting and was attended by twenty-five members. Prof. James Barnes of Bryn Mawr College gave a short talk on "Recent Ideas in Regard to the Spectrum." Dr. Wendell Reber gave a short address on "The Problem of the Relation of the Human Eye to Illumination, Natural and Artificial."

The following officers have been elected for the year beginning October 1: chairman, Prof. George A. Hoadley; secretary, L. B. Eichengreen; managers, F. C. Dickey, H. H. Ganzer, H. A. Hornor, H. Calvert and Samuel Snyder. Mr. Eichengreen was re-elected secretary.

PITTSBURGH SECTION.

At a meeting of the Pittsburgh Section in the auditorium of the Engineers' Society of Western Pennsylvania, Oliver Building, June 20, Messrs. Evan J. Edwards and Ward Harrison of the National Electric Lamp Association presented a paper entitled "Some Engineering Features of Office Lighting." The paper will be published in the next issue of the TRANSACTIONS, the October number.

Announcement was made of the election of the following officers for the ensuing year: chairman, C. J. Mundo; secretary, Alan Bright; managers, H. S. Hower, H. H. Magdsick, E. R. Roberts, C. E. Stephens and S. B. Stewart.

New Officers.

At the recent annual election of the Society the following officers were elected for various terms beginning October 1: president, Charles O. Bond; vice-president to represent the New York Section, George H. Stickney; vice-president to represent the Pittsburgh Section, Ward Harrison; general secretary, Joseph D. Israel; treasurer, L. B. Marks; directors, F. J. Rutledge, C. A. Littlefield, F. A. Vaughn. Directors are each elected for three years, vice-presidents, two years, and the other officers one year. Messrs. Israel and Marks were re-elected.

The results of the election for officers of the several sections may be found under the Section Notes in this issue.

CHARLES O. BOND, president-elect of the Illuminating Engineering Society, was born November 15, 1870, near the town of Lehigh, Webster County, Iowa. He was graduated from the United States Naval Academy, Annapolis, Md. in 1890. After graduation he served one year at sea on board the U. S. S. Enterprise and U. S. S. Philadelphia, resigning from the navy in 1891. He later taught school in the states of Iowa and New York for five years, and in 1897 became connected with the United Gas Improvement Company in Philadelphia. In 1898, during the Spanish-American War, he served five months as an ensign in the navy on board the U. S. S. Lancaster and the U. S. S. Newport. At the close of the war, he resumed his connection with the United Gas Improvement Company, taking charge of the photometric work of the company. While continuing in this position, he also held command of one division of the Naval Force of Pennsylvania for three years. Since 1909, Mr. Bond has been manager of the photometrical laboratory of the United Gas Improvement Company, which was established in that year.

Joseph D. Israel, who has twice been elected general secretary of the society, has been connected with the lighting industry during the past twenty-six years. He is at present district manager of the Philadelphia Electric Company.

Mr. Israel was born in Philadelphia, February 28, 1868. In 1886 he was graduated from the Scientific School of the University of Pennsylvania with the degree of Bachelor of Science. After a post-graduate year in mechanical and electrical courses, the same university conferred upon him the degree of Mechanical Engineer in 1887. Immediately after graduation he became connected with the Edison Electric Light Company of Philadelphia, devoting his time to underground street work. Shortly afterward he became superintendent of the street work of the company. He next became assistant to the manager of the company, and later was made secretary and manager. When the company was merged with the Philadelphia Electric Company he became district manager of the latter company.

Mr. Israel has been active in the local and national work of the Illuminating Engineering Society, the National Electric Light Association and the American Institute of Electrical Engineers. He is also a member of the Franklin Institute of the State of Pennsylvania and a director of the Commercial Section of the National Electric Light Association. He has contributed papers and reports to local and national meetings of the above-named societies, and the Association of Edison Illuminating Companies.

A Survey of Present Day Lighting.

The Illuminating Engineering Society, through its president, Mr. Preston S. Millar, is undertaking the preparation of an exhaustive survey of present day lighting conditions, the object being to record as nearly as possible the lighting practise in a number of different fields. It is expected that the survey will afford concrete information on the present situation and provide a basis of comparison for future estimates of progress. It will probably be of most value at the present time in enabling individuals and companies to compare their practises with general practise and conditions; it should disclose what is judged the most advanced practise in each field.

For the purpose of this survey the United States has been divided into eighty-nine different sections, each section containing approximately one million inhabitants. Into each district various lists of questions regarding illuminating practise are being sent to representative companies and individuals in the following professions and industries:

Central stations.

Gas companies.

Municipal engineers.

Manufacturers of incandescent lamps.

Manufacturers of mantle burner lamps.

Manufacturers of arc lamps.

Manufacturers of acetylene supplies, tips, etc.

Manufacturers of oil lamps.

Manufacturers of small isolated lighting plant equipments, gasolene, acetylene, etc.

Manufacturers of lighting glassware.

Fixture manufacturers.

Arc lamp post manufacturers.

Ophthalmologists.

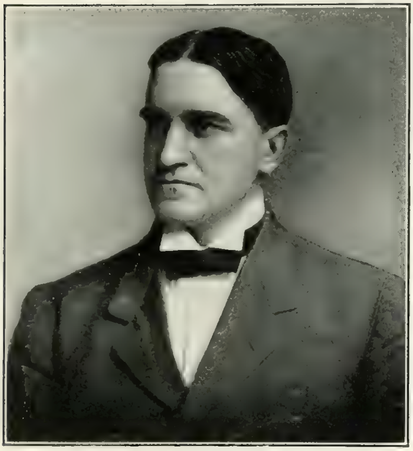
School associations and commissions.

Railroads.

Street railroad companies.

Street lighting lamp companies.

It is hoped, therefore, that with a reasonable amount of co-operation on the part of those to whom the questions are sent that estimates and



CHARLES O. BOND, President-elect.

JOSEPH D. ISRAEL, General Secretary.

data will be received from some two to three thousand persons, each of whom is probably best fitted to provide the information for which he is asked. In interpreting and summarizing the information, which it is hoped will be made available, an effort will be to emphasize that which is constructive and to avoid everything invidious. The final survey will be made up with the co-operation and advise of a number of men in the lighting industry, and no information will be used which will be likely to prove in any way derogatory to the interests of those contributing. The information derived will be used as a basis of a paper to be presented at the convention of the Illuminating Engineering Society in Pittsburgh during the week beginning September 22, 1913.

ANNOUNCEMENT BY COMMITTEE ON NOMENCLATURE AND STANDARDS.

The committee has tentatively adopted the following additional definitions:

Apparent candle-power, at a distance d, is the candle-power of the simple luminous source which at the distance *d* from the point of observation would give an illumination equal to the observed illumination.

The term should be used only for cases in which the law of inverse squares does not apply. The term is meaningless unless *d* is given.

Power consumed by a source, *P*, expressed in ergs per second is the total power input in a radiating body.

Power radiated by a source, $P_r = \int_0^\infty P_{r\lambda}\, d_\lambda$, the radiant power emitted by a source in the form of radiation between wavelengths zero and infinity, expressed in ergs per second.

Radiation Efficiency, $\rho = \frac{P_r}{P}$, a numeric, is the ratio of the power radiated to the total power consumed by a source.

Specific Consumption, the ratio of the power consumed by a source to the total luminous flux in lumens.

$$S = \frac{P}{F}.$$

Specific luminous output, the reciprocal of specific consumption, F/P.

The committee further would present to the membership the following definitions proposed by Dr. H. E. Ives and not yet acted upon by the committee. The committee desires the suggestions and criticisms of the membership on all of the definitions here given.

Available useful power for lighting purposes, $R_e = \int_{0.4\mu}^{0.8\mu} R_\lambda\, d\lambda =$ the radiation lying in the visible spectrum. (The power which gives one mean spherical candle of this radiation is sometimes called *the mechanical equivalent of a light*).

Visible fraction of the radiation from a source $= \frac{R_e}{R} =$ fraction of the total radiation useful for lighting purposes. (A pure

numeric). (This fraction is sometimes called the *radiant luminous efficiency*, the ratio $\frac{R_e}{P}$, the *total luminous efficiency of a light source*).

Radiant specific consumption $= \frac{R}{F} =$ power radiated per lumen $= \rho \frac{P}{F}$.

Radiant specific luminous output $\frac{F}{R} =$ lumens radiated per watt radiated $= K_m = \frac{F}{\rho P}$ (∴ identical with *stimulus coefficient*).

Note :—Watts per candle, candles per watt, watts per lumen, lumens per watt, are ratios sometimes called "*efficiency*."

Radiant Luminous Efficiency $= \mu_R =$ ratio of the radiant specific luminous output of a source to the maximum possible specific luminous output. (*A pure numeric*)

$$\mu_R = \frac{\frac{F}{R}}{\left(\frac{F}{R}\right)_{max}} = \frac{K_m}{K_{max}} = \frac{1}{K_{max}} \int_0^\infty K_\lambda \, R_\lambda \, d\lambda.$$

Total luminous efficiency $= \mu =$ ratio of the specific luminous output of a source to the maxium possible specific luminous output. (*A pure numeric*)

$$\mu = \frac{\frac{F}{P}}{\left(\frac{F}{P}\right)_{max}} = \frac{\frac{F\rho}{R}}{\left(\frac{F}{R}\right)_{max}} = \frac{K_m \rho}{K_{max}}.$$

Since maxium value of ρ is unity.

Note :—If K_{max} be taken as unity, *i. e.*, if the unit of flux be taken as that given by one power unit of radiation of maxium luminous efficiency, then considering the radiation from a source

$$\mu_R = \frac{F}{R} = \overline{K}_m,$$

or luminous efficiency = specific luminous output = stimulus coefficient (numerically).

For the *total radiation*

$$\mu = \frac{F}{P} = \rho \, \overline{K}_m,$$

or *luminous efficiency* is numerically the same as *specific consumption*.

C. H. SHARP,

Secretary Committee on Nomenclature and Standards.

Constitution and By-laws
of the
Illuminating Engineering Society

(Adopted by a vote of the Membership, January 14, 1907.)

Constitution amended: Jan., 1909; Jan., 1910; Jan., 1911; Jan., 1912; Dec., 1912. By-laws amended by Council: Jan. 28, 1907; Feb. 10, 1910; Mar. 10, 1911; Dec. 8, 1911; Jan. 12, 1912; Jan. 10, 1913.

ARTICLE I.

NAME AND OBJECTS.

Section 1: The name of this association shall be the Illuminating Engineering Society.

Section 2: Its objects shall be the advancement of the theory and practise of illuminating engineering and the dissemination of knowledge relating thereto. Among the means to this end shall be meetings for the presentation and discussion of appropriate papers; the publication as may seem expedient of such papers, of discussions and communications; and through committees, the study of subjects relating to the science and art of illumination, and the publication of reports thereon.

> (a) *Sec. 2:* The appointment of committees to report upon scientific and engineering subjects shall be authorized only by a majority vote of the Council, which shall be taken by letter-ballot. When such a committee is thus authorized, the President shall appoint the members thereof, subject to approval by vote of a quorum of the Council.

ARTICLE II.

MEMBERSHIP.

Section 1: The members of this Society shall be designated as Members, Sustaining Members and Honorary Members.

Section 2: A Member may be anyone interested in the objects of the Society. At the time of his election he shall not be less than twenty-one years of age.

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Section 3: A Sustaining Member may be a company, firm, association or individual interested in the objects of the Society and desirous of contributing to its support. A Sustaining Member, when other than an individual, may be officially represented by an individual. The privileges of Sustaining Members shall be the same as those of members, except the right to vote and to hold office. All provisions of this Constitution governing the admission, duties and obligations of members shall, unless otherwise provided, apply to Sustaining Members.

Section 4: Honorary Members may be chosen from among those who are of acknowledged eminence in some branch of art or science related to illuminating engineering. Honorary Members shall be entitled to all the privileges of the Society except the right to vote and to hold office therein.

ARTICLE III.

ADMISSION AND EXPULSION OF MEMBERS.

Section 1: Honorary Members shall be proposed in writing by at least fifteen members, and shall be elected only by the unanimous vote of the Council. Voting shall be by letter-ballot. A person elected an Honorary Member shall be promptly notified by letter, and the election shall be cancelled if an acceptance is not received within six months after the mailing of such notice.

Section 2: An application for admission to the Society shall be made in a form prescribed by the Council and shall bear the endorsement of at least two Members of the Society; or shall refer to at least two Members of the Society; or if an applicant certifies that he is not personally known to two members, references may be accepted to members of professional societies of good standing, or to other persons whose good standing may be readily verified.

(a) *Sec. 2:* An application for membership in the Society shall be made upon a printed form prepared by the General Secretary and approved by the Council, which shall call for such information as may be required by the Board of Examiners and the Council to pass properly upon the eligibility of a candidate.

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(b) *Sec. 2*: In the absence of replies from referees to inquiries for information, or if replies are not sufficiently explicit, the Board of Examiners having cognizance of the application shall cause the applicant to be notified and shall hold his application in abeyance.

Section 3: All applications for admission to membership shall be passed upon by a Board of Examiners of the section of the Society representing the locality in which the applicant resides. All applications shall be reported to the Council for final action. An applicant not residing within the territory of a section shall submit his application direct to the Council.

(c) *Sec. 3*: When applications for admission are received from persons residing within the territory of a section the General Secretary shall notify the Secretary of that section to make prompt report upon the application.

(d) *Sec. 3*: The privileges attaching to membership in the Society shall not be accorded to newly-elected members until they have paid their entrance fee and current dues. This by-law shall be printed upon the notification of election.

(e) *Sec. 3*: Upon receipt of an application for membership, which shall be made on the official form the General Secretary, or the Secretary of a section, shall see if it has been properly filled out. If not, he shall return the form and notify the applicant of the deficiency. When an application is in proper form it shall be forwarded to the chairman of the Board of Examiners. The Secretary of a section shall conduct for the Board of Examiners such correspondence with applicants and their referees as the Board may direct.

(f) *Sec. 3*: Objection to the admission of a candidate must be accompanied by specific reasons for such objection.

Section 4: A Member may resign from the Society by a written communication to the Secretary, which resignation shall be accepted by the Council if all his dues and other indebtedness have been paid, and the Society badge has been returned.

Section 5: Upon the written request of ten or more members that, for cause definitely stated in detail, a Member of the Society be expelled, the Board of Managers of the section of the locality wherein the accused resides shall consider the matter, and if there appears to be sufficient cause shall advise the accused of the charges against him. The accused may then present

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a written defense and appear in person before a meeting of the board. The finding of the board shall then be submitted to the Council of the Society which, within two months, shall finally consider the case, and if a satisfactory defense has not been made, the accused Member shall be expelled upon a two-thirds vote of the Council. In the case of one not a member of a section, charges shall be preferred directly to the Council.

ARTICLE IV.

DUES.

Section 1: An entrance fee, payable on admission to the Society, may be fixed by the Council.

> (a) *Sec.* 1: The entrance fee for members shall be $2.50 payable on admission to the Society. There shall be no entrance fee for Sustaining Members

Section 2: The annual dues for members shall be $5, which shall include subscription to the TRANSACTIONS of the Society.

> (b) *Sec.* 2: The annual dues are payable in advance. Bills for dues shall be sent out by the General Secretary not later than October 10.
>
> (c) *Sec.* 2: If the entrance fee and dues are not paid within one month after a member has been notified of his election, he shall be finally informed of the delinquency; and if such dues are not paid within two months from the time of notification of election, the Council shall cancel the election, of which cancellation the delinquent and his referees shall be informed. This by-law shall be printed on the final notice above provided for. (See also by-law *Sec.* 3, ART III.)
>
> (d) *Sec.* 2: Any member in arrears four months for dues, shall be informed by the General Secretary that he is delinquent and can have no vote or voice in the affairs of the Society or receive its TRANSACTIONS or other publications until the dues are paid. At the expiration of two months thereafter, if still in arrears, he shall be notified that his name will be presented to the Council as delinquent, if the dues are not paid within one month. If the member continues delinquent, the Council shall drop him from membership at the regular meeting held in June.
>
> (e) Sec. 2: From the annual dues paid by each Member $3 shall be deducted and applied as a subscription to the TRANSACTIONS for the year covered by such payment. The price of sub-

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scription of the TRANSACTIONS to non-members of the Society shall be $5 per year. Single copies may be sold at 55 cents each; provided that volumes reserved shall not be broken to furnish single copies.

(f) *Sec. 2*: The official badge of the Society shall be issued by the General Secretary upon application to any Member in good standing, upon payment of $3; provided that Honorary Members shall receive the badge without payment. Each badge shall be numbered and registered in the name of the member receiving it. Members purchasing badges shall be informed by the General Secretary that they are issued with the express condition that if the member resigns or is dropped from the Roll of the Society, he shall return his badge, receiving therefor the sum of $2.

(g) *Sec. 2*: A certificate of membership in the Society shall be issued by the General Secretary upon application to any member in good standing, upon payment of $1.00.

Section 3: The annual dues for Sustaining Members shall be not more than $250.00.

(h) *Sec. 3*: Dues (not exceeding $250 annually) for Sustaining Members may be elective with the Sustaining Member. TRANSACTIONS shall be sent free of charge to Sustaining Members whose dues are $10.00 or more per annum.

Section 4: Honorary Members shall be exempt from all payments.

Section 5: A Member elected after six months of the fiscal year have expired shall pay one-half of the amount of dues for that year; provided, that if he requests and receives a set of TRANSACTIONS covering the entire year, then the full annual dues shall be paid.

Section 6: A Member who has been dropped as delinquent may be reinstated by the Council and retain his original date of election upon payment of all back dues, being then entitled to a complete file of the publications of the Society, if in stock, corresponding to the period of delinquency.

ARTICLE V.

OFFICERS.

Section 1: The officers of the Society shall be a President, Vice-presidents equal in number to the number of organized Sections, nine Directors, a Secretary and a Treasurer.

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Section 2: The President, the Secretary and the Treasurer shall hold office for one year; the Vice-presidents shall hold office for two years and the Directors for three years. Terms of office shall commence the first day of October. A retiring President, Vice-president or Director shall not be eligible for immediate re-election to the same office, and a retiring Vice-president shall not be eligible for immediate election as a Director. At each annual meeting officers shall be elected to succeed those retiring by expiration of term.

Section 3: A vacancy in the office of President shall be filled by the senior Vice-president; a vacancy in the office of Vice-president shall be filled by the senior Director; a vacancy in the office of Director shall be filled by the Council, preferably by selection from members, if any, who at the previous annual election received votes for the office of Director. A vacancy in the office of Secretary or Treasurer shall be filled by the Council. Such succession to office or appointment by the Council shall not render an officer ineligible for immediate election to the same office. Seniority between officers of the same rank and date of election shall be determined by the date of their election as members.

Section 4: No officer shall receive, directly or indirectly, any salary, compensation or emolument from the Society, either as such officer or in any other capacity, unless authorized by a vote of the majority of the entire Council. No officer shall be interested, directly or indirectly, in any contract relating to the operations conducted by the Society, nor in any contract for furnishing supplies thereto, unless by the unanimous vote of the Council.

ARTICLE VI.

ELECTION OF OFFICERS.

Section 1: Each year not later than April 1, a Board of Nomination, consisting of the two junior Past-presidents and of the Past-vice-presidents whose terms of office expired in the two preceding Septembers, shall proceed to prepare a nomination ticket containing the names of those whom they deem best suited for the offices to be filled at the ensuing annual election. Nomi-

nees for the office of Vice-president shall be so selected that, if such nominees are elected, each locality where there is a Section of the Society may be represented on the Council by a Vice-president.

(a) *Sec.* 1: Each year, not later than March 15, the General Secretary shall send to the senior Past-Officer among those designated in Article VI, Section 1, a copy of that section and the names and addresses of the other Past-Officers therein designated. The senior officer shall then forthwith proceed to organize the Board of Nomination and shall submit its report to the General Secretary not later than April 25.

Section 2: The ticket thus prepared shall be printed and forwarded to members not later than May 5 together with an unmarked inner envelope, and an outer official voting envelope bearing the name and address of the Society and the words, "Official Voting Envelope—Enclosing a Ballot Only." The member voting shall enclose his ballot in the unmarked envelope, which shall, in turn, be enclosed in the outer envelope, which latter shall be endorsed with the name of the sender. Ballots to be counted must reach the General Secretary not later than May 26.

(b) *Sec.* 2: The General Secretary shall have printed and enclose with the official nomination ticket, Section 2 of Article V, and Sections 1, 2 and 3 of Article VI.

(c) *Sec.* 2: The roll of members shall designate those who are charter members of the Society. The names of present and past general officers shall be followed by the name of office held, printed in italic type.

Section 3: A member may vote the official ticket above provided for; or he may erase any names thereon and substitute others; or he may substitute a written ballot containing names of his own selection.

Section 4: The President at a Council meeting in May shall appoint, subject to the approval of the Council, five members, not members of the Council, to constitute a Committee of Tellers. This committee shall meet between May 26 and May 30, and shall receive unopened all ballots from the General Secretary and shall forthwith proceed in secret to count the vote. It shall then

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prepare in duplicate and sign a report of the results of the vote, one copy of which shall be delivered to the General Secretary and the other handed by the chairman of the committee, at the ensuing annual meeting, to the presiding officer, who shall at the opening session of the meeting announce the names of the officers elected.

(d) *Sec.* 1: The General Secretary upon receipt of the report from the Committee of Tellers, shall at once notify the president-elect of the result of the election.

ARTICLE VII.

MANAGEMENT.

Section 1: The affairs of the Society shall be managed by a Council under this Constitution and under the By-Laws adopted for the execution thereof. The Council shall direct the business of the Society either itself or through its officers and committees.

Section 2: The Council shall consist of the officers of the Society and of the two junior Past-presidents.

(a) *Sec.* 2: Regular meetings of the Council shall be held once each month, except during July, August and September. Special meetings of the Council or of the Executive Committee may be called by the President. Notice of such special meetings shall be forwarded to the members of the Council or of the Executive Committee at least three days in advance of the meeting. The notice shall contain a synopsis of the business to be brought before the special meeting, and no business other than that so specified shall be transacted at such meeting.

(b) *Sec.* 2: The General Secretary shall, after each meeting of the Council, forward to each member thereof a transcript of the minutes of the meeting.

Section 3: The Council may delegate any or all of its powers to an Executive Committee of five members, consisting of the President, the Secretary and the Treasurer, ex-officio, and two other members of the Council, which committee shall conduct the affairs of the Council between its meetings.

(c) *Sec.* 3: Should the Executive Committee have taken any action between meetings of the Council, it shall report such action at the first meeting of the Council following; if approved, the action of the Executive Committee shall be as if the action of the Council.

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Section 4: The President shall have general supervision of the affairs of the Society under the direction of the Council. He shall preside at the meetings of the Council at which he may be present and shall be ex-officio member of all committees. He shall deliver an address at the annual convention of the Society.

Section 5: Vice-presidents or Directors, in order of seniority, shall preside at meetings of the Council in the absence of the President.

Section 6: The Treasurer shall be the custodian of all moneys. He shall make an annual report, which shall be audited, and such other reports as may be prescribed. The Treasurer and the Secretary, with the advice and consent of the Committee on Finance, shall invest such funds as may be ordered by the Council. They shall pay all bills when audited by the Committee on Finance and approved by the Council.

Section 7: The General Secretary shall be, under the direction of the President and the Council, the executive officer of the Society. He shall prepare the business for the Council and record the proceedings thereof. He shall collect all moneys due to the Society, and deposit the same subject to the order of the Treasurer. He shall personally certify the accuracy of bills or vouchers upon which money is to be paid and shall draw and countersign all checks, which shall be signed by the Treasurer when such drafts are known by him to be proper, duly authorized by the Committee on Finance and in accordance with the necessary vouchers transmitted by the General Secretary with the draft. He shall have charge of the books and accounts of the Society and shall furnish monthly to the Council a statement of receipts and expenditures and monthly balances. He shall present annually a report to the Council for publication in the TRANSACTIONS, and from time to time shall furnish such statements as may be required. He shall conduct the correspondence of the Society and keep full records and perform such other duties as may be assigned to him. The Council may appoint assistants to the General Secretary; one of these may have the title of Assistant Secretary, and shall be under the immediate direction of the General Secretary and aid him in all matters.

In the event of prolonged absence or disability of the General Secretary or Treasurer the Council shall authorize one of its members to sign or countersign checks.

(d) *Sec.* 7: The accounts of the General Secretary and the Treasurer shall be audited annually just prior to the annual meeting.

Section 8: The President shall, at the first meeting of the Council after he assumes office, appoint, subject to the approval of the Council, the following standing committees: a Committee on Finance, of three members; a Committee on Papers, of at least five members; a Committee on Editing and Publication, of three members. He may also appoint temporary committees from time to time. Two of the three members of the Finance Committee shall be members of the Council, and the other standing committees shall include at least one member of the Council.

(e) *Sec.* 8: The Council shall appoint a General Board of Examiners to pass upon applications for membership received from persons not residing within the territory of any section.

Section 9: All committees shall be directly responsible to the Council, and shall act under its direction. The Council may at any time, at its own discretion, remove any or all members of a committee, and thereupon the President shall forthwith appoint others as hereinbefore provided; in the failure of the President duly to appoint such a committee, the Council may make the appointment. The terms of the members of all standing and temporary committees shall terminate at the time of the first Council meeting of the new administration of each year. In case of failure to appoint new standing committees on Finance, on Papers and on Editing and Publication, the retiring committees shall continue to act until their successors are appointed.

(f) *Sec.* 9: So far as possible, all reports of committees to the Council shall be in writing and signed by all the members of the Committee, or an explanation shall be offered by the chairman for the absence of any signature. If only an oral report of committee work can be rendered, the chairman or other member making such report shall state if the subject matter has been submitted to the other members of the committee, and shall offer an explanation if this has not been done.

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Section 10: The Committee on Finance shall have direct supervision of the financial affairs of the Society, and shall present to the Council an annual report on its financial condition. It shall approve all bills before payment, and shall make recommendations to the Council as to the investment of moneys and upon all specific appropriations. No payments other than routine office expenses shall be made by the General Secretary or Treasurer, except upon the authorization of the Committee on Finance.

Section 11: The Committee on Papers shall have general supervision of all papers to be presented before the Society, and shall have the duty of preparing the programs of general meetings of the Society and procuring papers for presentation before such meeting. No paper, discussion, communication or report shall be printed in the TRANSACTIONS of the Society or elsewhere until approved by the committee.

(g) *Sec.* 11: The Committee on Papers may direct the Committee on Editing and Publication to make such revision as may be considered necessary or desirable, of papers and communications offered for publication; in case of such revision the manuscript shall be returned to the author to obtain his consent thereto, and should such consent be refused, the paper or communication shall not be accepted for presentation before the Society.

(h) *Sec.* 11: The acceptance of a paper or communication for presentation before the Society or any section thereof shall not be considered a guarantee of its publication in the TRANSACTIONS.

Section 12: The Committee on Editing and Publication shall edit all discussions of papers presented before the Society or any section thereof, and shall decide all questions of detail regarding the publication of papers, discussions and communications. The TRANSACTIONS and other publications of the Society shall be in direct charge of this committee.

(i) *Sec.* 12: The Committee on Editing and Publication may, at its discretion, abridge discussions for printing. The Committee shall cancel remarks that do not bear directly on the subject under discussion, or deal in personalities or have manifestly a purely commercial object.

(j) *Sec.* 12: All papers, discussions and other matter intended for publication in the TRANSACTIONS shall, so far as possible, be revised and edited in manuscript and not in proof.

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(k) *Sec.* 12: A revised report of any member's discussion on any paper must be received at the general office of the Society within ten days after it has been mailed to the member, otherwise revision shall be made by the Editing Committee.

(l) *Sec.* 12: The TRANSACTIONS of the Society shall be issued monthly, except during the three summer months.

Section 13: Five members shall constitute a quorum of the Council. The "Vote of the Council" shall be a vote of the majority of the members present and forming a quorum, except where a letter-ballot is prescribed, when the "Vote of the Council" shall be a vote of the majority of the entire membership of the Council.

ARTICLE VIII.

MEETINGS.

Section 1: The annual meeting of the Society shall be held on the second Friday of June of each year at a place designated by the Council, when a report of the proceedings of the Society for the past fiscal year shall be presented by the Council, which report shall be verified by a majority of the Council, including the President, Treasurer and General Secretary.

Section 2: An annual convention of the Society shall be held on a date and at a place fixed by the Council, for the presentation and discussion of professional papers and subjects. The President shall deliver a presidential address at this meeting.

Section 3: Other meetings of the Society as a body may be held at such time and place as the Council shall direct, at which no business affecting the organization or policy of the Society shall be transacted. Notice of all such meetings shall be sent by mail or otherwise to all members at least ten days in advance of a meeting.

ARTICLE IX.

SECTIONS.

Section 1: Sections of the Society may be authorized in any State or locality where the membership exceeds 50.

(a) *Sec.* 1: Upon petition for the authorization of a section of the Society, the Council may accord such authorization if the necessary membership exists within the locality specified in the petition.

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(b) *Sec.* 1: Meetings of sections shall be held at times and places fixed by the Board of Managers. When suitable papers or lectures are available, meetings may be held preferably monthly except during the three summer months.

(c) *Sec.* 1: The meetings of the sections shall be held preferably before the 15th of the month.

Section 2: Each section shall nominate and elect a Chairman, five Managers and a Secretary.

Section 3: The officers of a section shall be elected annually by the members affiliated with the section, the election to be in accordance with a procedure fixed by the Council.

(d) *Sec.* 3: Procedure in nominating and electing section officers shall be as follows, except when other procedure shall be authorized by the Council:

A section nominating committee shall be appointed by the Section Board of Managers at a meeting held not later than March 1 of each year. The appointment shall be reported to the General Secretary. This committee shall consist of five members of whom at least two shall be past officers of the section or members of the Council.

Not later than March 15 of each year, the General Secretary shall notify the chairman of the committee that it is the committee's duty to prepare a nomination ticket containing the names of those whom they deem best suited for the section offices to be filled at the ensuing annual election. The report of the committee shall be prepared in duplicate, one copy shall be submitted to the chairman of the section and the other copy shall be delivered to the General Secretary not later than April 25. The ticket thus prepared by the committee on nomination shall be printed and forwarded to all section members not later than May 5, in connection with the ballots for election of general officers. The election of section officers in other respects shall be carried out in a manner similar to that prescribed for the election of general officers, save that a copy of the report of the Committee of Tellers on the results of the section election shall be mailed as soon as prepared, to the chairman of the section and to the Chairman-elect.

Section 4: The business of a section shall be conducted by a Board of Managers, which shall consist of the Vice-president of the Society representing the locality of the section, and the Chairman, Managers and Secretary of the section.

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Section 5: The Section Board of Managers shall annually, at the first meeting of the society year, appoint a Board of Examiners to pass upon applications for membership.

> (e) *Sec.* 5: The Board of Examiners of a section shall consist of the Chairman, the Secretary and one Manager of the section.

Section 6: A section may formulate by-laws for its conduct, which shall conform with the Constitution and By-Laws of the Society and with the policy of the Society as fixed by the Council. Upon approval by the Council, proposed By-Laws may be adopted by a two-thirds vote at a regular or special meeting of the section; notification of such meeting, together with a copy of the proposed by-laws shall be sent to all members of the section at least ten days prior to the date fixed for its holding.

Section 7: Any proposed action of a section not relating to the holding of meetings and the discussion of papers shall be submitted to the Council of the Society for approval prior to being put into execution.

Section 8: The expenses of sections incurred for postal-card notices of meetings shall be paid from the general fund of the Society. In cases where there is no desirable auditorium available free of charge, the Council shall authorize the rental of a hall, the expense to be payable from the general fund of the Society. Other expenses than these to be payable from the general fund of the Society must first be authorized by the Council of the Society.

> (f) *Sec.* 8: The Treasurer may deposit with the Secretaries of sections a sum of money, the amount to be fixed by the Council, to provide for current expenses.
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> (g) *Sec.* 8: The General Secretary of the Society shall supply to each section all stationery and printing, aside from postal-card notices necessary for the conduct of its business.

Section 9: A Section Board of Managers may authorize, and shall provide for the payment by local assessment of any expenses of a section beyond those authorized to be paid from the general fund of the Society.

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Section 10: Papers shall be approved by the Section Board of Managers prior to presentation before a section. Manuscript of papers approved should be forwarded to the Committee on Papers sufficiently in advance of date of presentation to enable advance copies, if a paper be approved by that committee for general presentation, to be printed and sent to all sections for distribution prior to presentation before the sections.

Section 11: Reports of discussions shall be forwarded promptly to the General Secretary who shall mail them at once to members for revision.

(h) *Sec.* 11: The Secretaries of sections shall, after each meeting, send to the General Secretary a statement of the attendance and of the business transacted.

(i) *Sec.* 11: The Secretary of each sction shall forward to the General Secretary, not later than five days after a meeting of a section, the proceedings of the meeting for publication in the TRANSACTIONS.

(j) *Sec.* 11: The Secretaries of sections shall send monthly to the General Secretary an account of all expenditures in the preceding month.

Section 12: Should the membership of a section fall below 50, or the average attendance at meetings not warrant the expense of maintaining the organization, the Council may cancel its authorization.

Section 13: Sections shall abide by the Constitution and By-Laws of the Society and conform to the regulations of the Council. The conduct of sections shall always be in conformity with the general policy of the Society as fixed by the Council.

ARTICLE X.

LOCAL REPRESENTATIVES.

Section 1: When authorized by the Council, the President shall appoint, subject to the approval of the Council, local secretaries or local committees resident in cities or localities where it may be deemed desirable to provide representation with a view to promoting the work of the Society.

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(a) *Sec.* 1: Local secretaries shall communicate to the General Secretary, information concerning local developments in which the Society may be concerned; shall endeavor to promote occasional meetings under the joint auspices of the Illuminating Engineering Society and local organizations with a view to fostering interest in the work of the Society and shall in any other manner which may commend itself seek to develop local knowledge concerning the objects of the Society and to advise the General Secretary when opportunities arise for the Society to promote its objects.

(b) *Sec.* 1: Local secretaries may obtain Society stationery upon application to the General Office. Local secretaries' expenses for the correspondence may be billed to the Society.

ARTICLE XI.

GENERAL.

Section 1: The fiscal year of the Society shall be October 1 to September 30.

Section 2: A quorum of the Society shall consist in number of one-tenth of the total number of members as listed in the Society's records at the close of the last fiscal year.

ARTICLE XII.

AMENDMENTS AND BY-LAWS.

Section 1: Proposals to amend this Constitution shall be made in writing to the Council and signed by at least 100 members and shall reach the General Secretary not later than April 1. The Council shall consider such proposals and direct the General Secretary to send out a letter-ballot on their adoption. Votes to be considered shall be received not later than May 26, and shall be referred unopened to the Committee of Tellers who shall count such votes and make a sealed report, which shall be presented at the annual meeting. An affirmative vote of two-thirds of the entire vote cast by qualified members of the Society shall be necessary to secure the adoption of an amendment. An amendment shall take effect twenty days after its adoption.

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Section 2: By-Laws in interpretation of the spirit and letter of this Constitution and for its execution may be adopted by a majority vote of the entire Council. Votes on by-laws shall be by letter ballot. Each by-law proposed or adopted shall state the article and section of article of the Constitution to which it relates.

> (a) *Sec.* 2: A proposed by-law shall not be acted upon at the same meeting of the Council at which it is submitted. At least ten days before the Council meeting at which a by-law will come up for definite action, a copy of the same shall be forwarded to each member of the Council.

By-laws are printed in small type.

TRANSACTIONS

OF THE

Illuminating Engineering Society

JUNE, 1913

PART II

Papers, Discussions and Reports

[JUNE, 1913]

CONTENTS -- PART II

SOME HOME EXPERIMENTS IN ILLUMINATION FROM LARGE AREA LIGHT SOURCES.

BY HERBERT E. IVES.

Synopsis: The experiments here described were carried on with the consideration of efficiency subordinated. The problem was to obtain a pleasing satisfactory illumination, regardless of cost or of established ideas. Chief attention was paid to direction, diffusion and absence of glare. Means of measuring these qualities not being established, the criterion adopted was the writer's judgment. An analysis of light sources is made on the basis of size, intrinsic brilliancy, direction of light and whether the principal light source is visible or concealed. A study of a case of satisfactory daylighting from windows shows the window to be essentially a large area concealed light source at the side. A number of experimental artificial windows are described, leading to an estimate of the cost of an exact copy of daylight.

INTRODUCTION.

There is an old saying that "shoemakers' children go barefoot," and it is a matter of common observation that illuminating engineers have little time to study the lighting of their own homes. This should not be, of course, for a "doctor should have faith in his own medicine." But, over and above such considerations, is the fact that the least cultivated, but probably most important, field for good work in illumination is the lighting of the home. It is an almost everyday experience for us to see houses which are beautiful by day, but at night are actual atrocities—monuments to a lack of the most elementary conception of the lighting problem on the part of the architect.

It was in the effort to light my own home satisfactorily that the experiments to be described were begun. As time went on, however, the problems studied became somewhat varied, until lately attempts to copy daylight distributions of illumination have occupied most of his attention. The matter which follows is somewhat rambling, and the experiments somewhat incomplete, for reasons given; but as the next stage of the work may be delayed for some time it was thought well to publish this much, if for no other reason than for the discussion which may result.

* A paper presented at a meeting of the Philadelphia section of the Illuminating Engineering Society, May 16, 1913.

Out of this study have come some novel lighting devices and some new lighting schemes which are thought worth recording. Also, in the course of the work brightness measurements of different conditions were made which bring out points of interest.

ADVANTAGES AND DISADVANTAGES OF HOME EXPERIMENTS.

A great advantage of using one's own house as an illumination laboratory is that one can live with the lighting system and learn how it wears, as the various normal activities are carried on at their normal times. The home rooms have their furniture in place, which is a tremendous advantage. Everyone who has moved to a new house knows how very different a room appears before and after furnishing. It is the difference between discomfort and comfort, and to attempt to judge a lighting scheme in a bare laboratory room means too serious a handicap. Often a mere touch of decorative treatment will reclaim a lighting device which, in its crude form, is hard to imagine desirable.

The disadvantages are several. A considerable one is that it is difficult and often impossible to make changes in the positions of the outlets. A certain amount of flexibility is achieved by using base-board connections, but after a more or less unsightly structure of wires or tubes has arisen, the time is likely to come when something logically next on the program cannot be tried out without rebuilding the house. This limits experimentation, consequently some of the things described in this paper are incomplete, and the descriptions must end with suggestions as to what might be better. The usual separation from proper tools and the time taken to make what should be trivial changes constitute other disadvantages. A special house with furniture complete would possibly be the right thing for a study of this kind, but even this would labor under the disadvantage that one would be likely not to feel "at home," and would not be apt to live in it long enough to determine how it wore.

A CHARACTERISTIC OF HOME LIGHTING.

A characteristic of home lighting which makes it well worth studying by a lighting company is that efficiency counts for little. Furniture and pictures are not bought for their cheapness,

neither should light be—nor will it when the public becomes better educated in the use of light and in its remarkable decorative possibilities. In domestic lighting the real problem is to obtain a pleasant illumination effect, almost without regard to cost. In the experiments here described no attention whatever has been paid to efficiency. The author has put himself in the position of a householder who demands certain lighting effects and is willing to pay for satisfaction. In fact, I believe that many possible lighting schemes have not been tried at all—notably copies of daylight distribution—because the illuminating engineer has been apt to think too quickly of efficiency. He has been an engineer before being an artist, whereas the more fruitful procedure is to first obtain the desired effect and then count the cost. It may happen that the price of the paint prevents the painting of a masterpiece. Even if it costs too much now to have just what we would like, we must look forward to the day of more efficient light sources. We may even bring that day nearer by finding greater needs for them.

MEASUREMENTS AND MEASURING INSTRUMENTS.

This paper is to be comparatively free from foot-candle values, watts per square foot and the like. The chief points aimed at are diffusion, proper direction, freedom from excessive contrast and glare, a pleasant non-fatiguing quality and good appearance. How can these be measured? In the writer's opinion the only reliable and sensitive instrument is the experienced eye of one who has observed and thought about illumination for a period of years. We have all of us noticed how sensitive we have become to exposed light sources. Formerly they irritated us, to be sure, but we did not know the cause. Now we choose our position with care, shield our eyes with our hands, and in other ways give testimony to the vastly increased sensitiveness of our seeing mechanism. Meanwhile it remains a sad fact that we have generally available no method of measuring lighting conditions which will do more than distinguish between two so extreme in quality that a mere casual glance will tell which is good and which is bad. Until we are better off in this respect the trained eye must be encouraged as the best we have. It is worse than

useless to make measurements of factors which are not the ones really vital. If home illumination demands diffusion and a feeling of comfort meter-candles illumination on the working plane has very little to do with the problem. It must be borne in mind that measurements are of no value unless they record conditions whose qualities are proved by experience. Experience can never be dispensed with. It must be called upon sooner or later. This paper deals with lighting schemes whose measuring instrument at present is experience. Recognizing this fact I have outspokenly given here as the final criticism my own judgment of the success of an installation. In all cases however, I have had as many comments and suggestions from others as I could obtain.

REMARKS ON DIRECTION, DIFFUSION, GLARE AND CONTRAST.

One peculiarity of daylight illumination from windows is its direction. Most artificial systems cast the light downward from a point near the center of the ceiling. There then occurs in changing from day to artificial light a 90 degree rotation of shadows. By day they are long and sweep across the room; by night they are short or completely covered by the shadow-casting object. A clear illustration of this change is to be seen in the ordinary railway car. By day the illumination comes from the windows at the two sides; at night from the high centrally placed units. As far as direction is concerned, side wall brackets, floor standards or table lamps on side tables approximate more nearly to window conditions.

Diffusion of light with soft shadows, as is well known, is most perfectly brought about by the use of a large area of light source and is one of the chief merits of the "indirect" system. A certain degree of diffusion may also be obtained by a multiplicity of light sources, although this is apt to give merely a multiplicity of sharply defined shadows, instead of the soft shadows of the large source. The ordinary window with its area of 5 or 6 square feet (0.46 or 0.56 sq. m.), gives a far better degree of diffusion than most artificial schemes. Another factor in diffusion is the color of the light. Blue light diffuses better than yellow. It is therefore quite possible that daylight is inherently apt to be better diffused than is yellow artificial light.

In regard to contrast and glare, it is well to bear in mind some numerical data. A Welsbach mantle has an intrinsic brilliancy of 35 candle-power per square inch (6.45 sq. cm.); a tungsten filament about 1,000 and a patch of sky about 2 to 3. For the same intensity of illumination, that is, the same general brightness of illuminated objects, therefore, the physical contrast between the brightness of the illuminated objects and the light sources themselves will be from ten times to hundreds of times greater with visible "direct" artificial light than with daylight. If the light sources are concealed, this contrast may be avoided, but it occurs again to a disturbing degree if specularly reflecting surfaces are present. These reflect images of the light sources with about $^1/_{10}$ or $^1/_{20}$ of the intrinsic brightness of the parent source. It is, in fact, immediately evident to an expert whether the lighting of a room is due to small or large sources by an inspection of these two things—the sharpness of the shadows and the brightness of the specular reflections. Half of this handicap of small sources is eliminated by entirely avoiding specularly reflecting surfaces.

SOME CHARACTERISTICS OF DAYLIGHT OUT-OF-DOORS.

Out-of-doors daylight may be pleasant or unpleasant. In a previous paper* which records brightness measurements of typical outside illuminations, certain conditions were found to be most pleasing. These were an excess of brightness in the upper hemisphere, usually with a maximum near the horizon, and (a very essential condition) sunlight directed from the side to give long shadows.

A criticism which has been made of many "indirect" installations is that the bright "sky" furnished by the light ceiling is bounded by dark walls carried up above the eye line. This gives an effect of being down in a well, or as though the room had been lifted up away from one. To produce a real out-of-doors daylight distribution, the above quoted work would call for an extension of this brightness down to the horizontal. This would tend to overcome an objection frequently made to the 'indirect" system—that faces are subject to unnatural downward shadows.

* The Distribution of Luminosity in Nature, TRANS., I. E. S., p. 687, Vol. VI (1911).

Out-of-doors our faces receive considerable horizontal illumination. In addition the habit of wearing hats must be taken into account. Hats protect the eyes from overhead bright areas and also reduce the vertical component of the illumination on the face.

The effect of the large sky angle on the extreme brightness ratio must not be overlooked. Out-of-doors the sky approximates to an infinite plane. Under this a white surface will be as bright as the illuminant while other objects will be bright in proportion to their reflecting powers. As the area of "sky" is decreased, its brightness remains the same, but that of illuminated objects becomes less, thereby increasing the extreme brightness ratio between unconcealed illuminant and illuminated objects. Diffusion is also decreased and shadows take on a more definite downward direction.

AN ATTEMPT TO COPY OUT-OF-DOORS DIFFUSED DAYLIGHT.

The guiding idea here was to carry the direct illumination of an "indirect" system down on to the walls in such manner as to approximate the out-of-doors conditions, and thereby produce a pleasant diffused illumination. The room available was a

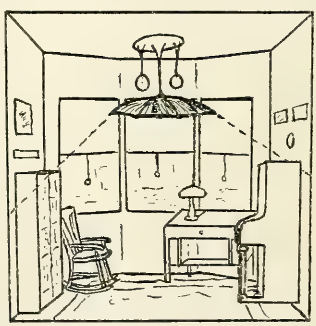

Fig 1.—Diffused illumination from side walls.

small one, about 14 feet (4.27 m.) square, furnished with a central fixture and papered a medium light buff. Under this central fixture was suspended a yellowish Japanese umbrella of oiled paper, convex side up. The direct light of the lamps thus fell on the walls, which acted as the chief light source of the room, since the transmission of the umbrella as used was low, while the

ceiling was little brighter than the walls and largely invisible because of the comparatively small size of the room. (See Fig. 1.)

A peculiar merit of this scheme lay in the splendid illumination of the pictures on the walls. These had to be slightly tilted to prevent reflection of the bright light sources, and in the direction of the entrance doorway a translucent Japanese fan was placed above the umbrella to conceal the lights. This installation was used for many months and gave great satisfaction. The "well" appearance sometimes noted in indirect systems was entirely absent. There was no tendency for the eye to wander upward to a bright point above. Although the illumination seemed low, it proved ample for sewing and other close work, which was done without the fatigue customary to working with "artificial" light. A pleasing addition to the general diffused lighting was furnished by placing a table lamp on one side, whereby the direct light of the sun was copied. One point proved to my satisfaction by this experiment is that light walls, well illuminated, are not productive of evil. On the contrary, they help in a marked degree the general effect of brightness. A room looks brighter with bright walls and, unless some extreme case is taken this means that the object—to light the room—has been attained.

This lighting arrangement was only given up when I moved away from Cleveland. It needs a small room, or, in a large room, a number of ceiling outlets not far from the walls in place of one central one. It is intended at some future time to place outlets in a large room which will make possible lighting the walls in a similar manner and the expectation is that it will furnish a very satisfactory illumination. In some indirect or semi-indirect installations it might be of interest to tilt the units near the walls in order to secure a similar effect. These units might be made purposely unsymmetrical.

CLASSIFICATION OF LIGHT SOURCES.

The common classification into direct, indirect and semi-indirect, while convenient, is by no means a complete analysis. The true classification is on the basis of the size of the light source and whether it is concealed or visible. The earlier light sources,

such as the gas flame and the carbon filament were small sources of relatively high intrinsic brilliancy. From them we have been working toward large light sources of lower intrinsic brilliancy. The fact that some of these are large areas of diffusely reflecting ceiling and that others are large areas of diffusely transmitting glassware is of no great significance. It is of significance that the light source is of large extent and of low intrinsic brilliancy. It is also of significance that in each of these cases ("indirect" and "semi-direct") the principal light source is visible. By "principal light source" I mean the source which furnishes the greater part of the light which falls on floor, furniture and working plane. It is also of great importance that as ordinarily worked out, in "indirect" and "semi-indirect" installation, the *light source is of necessity the brightest object in the field of view.* Therefore, the indirect and the semi-indirect systems sift down to this: that the unconcealed light source is made as large as is possible in the attempt to make its intrinsic brilliancy low and bearable. Incidentally this causes great diffusion of light and soft shadows.

In some forms of "direct" lighting another device is employed, namely, partial or complete concealment of the light source. In this case it may result that the principal light source is not the brightest object in the field of view. If the concealment is sufficient there may be a complete absence of points of high intrinsic brilliancy—more so than in the "indirect" system—except for points of specular reflection of the light sources if polished surfaces are present. These latter are of high intrinsic brilliancy in the "direct" systems and low in the "indirect."

It will be noted by those who have followed this analysis that while we have lighting systems with large, visible, low-brightness sources, and systems with small, either visible or invisible, high brightness sources, there are none consisting of *large, low brightness concealed light sources*—(with the possible exception of some forms of deck lighting where the light is carried well above a transparent or only partly diffusing glass). As will be pointed out later, this is the specification (when that of direction from the side is included) of pleasant daylight illumination from windows.

A LARGE OVERHEAD LIGHT SOURCE.

It follows from the classification just given that the characteristics of "indirect" lighting would be obtained without the process of reflection if a large enough low-brilliancy source was used. This was experimentally accomplished in a very simple manner by the use of a yellowish oiled paper Japanese umbrella of 4 feet diameter, turned point down, within which are the lights in frosted globes. (See Fig. 2.) A certain amount of light falls on the ceiling, so that it might be called a "semi-indirect" system, but by far the greater part of the illumination is due to the visible light source. This is of rather low intrinsic brilliancy, so that it can be looked at without any sensation of strain, and gives ample light all over the 16 foot by 20 foot room with an emission of about 7,500 lumens.

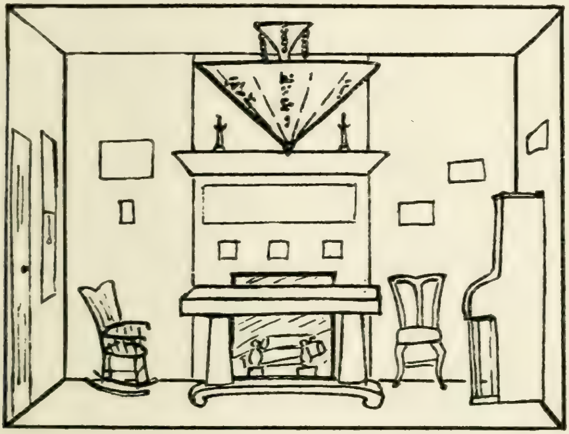

Fig. 2.—Illumination from large area, low brightness overhead source.

Now as to its merits and defects. Because of the size and low intrinsic brilliancy shadows are soft and specular reflections are too dull to be annoying. Because of the conical shape a better illumination of the walls and far corners is obtained than would be possible by a ceiling reflection scheme. On the other hand, the direction of the shadows is, for the center of the room at least, straight down and, therefore, different from the most agreeable daylight condition. But the greatest defect lies in the fact that the principal light source is visible, and, low as is the

intrinsic brightness, it is the brightest object visible and is too bright to be continuously in the field of vision. When the occupants of the room sit around the center table or sit sideways to the light, the illumination is extremely satisfactory. If, however, when a number of people are conversing, they face each other across the center, then in time the large bright umbrella becomes an irritant—far less, of course, than would the usual bright points, but still noticeable to a sensitive and critical eye.

An experiment was tried with a still larger light source, but it had the same defects. The conclusion was arrived at that by no process of increasing the size of the source, unless it actually occupied the whole upper hemisphere—which is out-of-doors daylight on a sunless day—could the light source be made innocuous. Diffusion is not alone sufficient. Any system by which the light source is the brightest visible thing gives an extreme brightness ratio which is too great to wear well. If, in the room illuminated with the large umbrella, the hand is held over the eyes, or an eye shade is worn, it leaves little to be desired; there remains merely the question of the direction of the light to be objected to; indeed many might prefer the centrally located source. Of course the higher the light source the less this defect would be, so that the "indirect" practise of making the ceiling the real source chooses the best condition, for it then approximates, in a small room, to a concealed source.

What seems to be most desirable in this particular room is some means of illumination with this large low brightness source, at the same time keeping it concealed. That done, the range of visible brightness is not too great. As will be seen below, daylight illumination by windows does something of this sort.

CHARACTERISTICS OF PLEASANT DAYLIGHT ILLUMINATION FROM WINDOWS.

I have no brief for daylight illumination in general, nor for all kinds of window lighting. Excessively unpleasant illumination may be found by day. On the other hand, daylight at its best has never, in my opinion, had a rival for general excellence. There has been much discussion on this point, some

declaring flatfoot for daylight as necessarily best, others recording themselves as preferring the "mellow," "cozy" artificial light. As a matter of fact, I believe no one has ever had a good copy of daylight to use at night in place of the ordinary artificial systems. Perhaps it is a case of "sour grapes" with those who say they would not copy daylight if they could. I believe, too, that illuminating engineers have neglected analysis of the good and bad points of daylight. Without such analysis it is futile to hope to copy the merits or avoid the defects.

My observation, common to that of others, is that window lighting is not always satisfactory. It may be insufficient, or it may cause excessive contrast in brightness. In my own house the first floor living room has one door and one window on the front and two windows at the side facing another house. Ordinarily the room is not sufficiently lighted by daylight. The front window is too narrow. If the shade is run up to the top it is impossible to look with comfort at the window, because the large patch of bright sky then visible is in violent contrast to the unilluminated wall at the sides of the window. Even with the shades down, so that the sky is not seen, the houses opposite are apt to present too great contrast of brightness to the walls adjacent to the window. Only under one condition is the daylight really satisfactory and that is when a spot of sunlight falls well back on the floor, the houses opposite being in the shade. Then the walls adjacent to the window receive light from the floor, the ceiling receives light from the floor and from the pavement outside and all is bright and cheerful. With snow on the ground outside, the effect is still better.

Another case of bad daylight illumination is furnished in the upper floors of a tall office building which is not faced by any other structure. If one sits facing a window, one sees a large expanse of bright sky, which soon becomes painful. In these rooms the official habitually places his desk so that his back is toward the windows. Visitors who face the windows do not find daylight pleasant.

Most fortunately a case of the other kind is to be found in my own house, namely, an instance of a pleasant and satisfactory daylight illumination. This is in a second floor room, facing

south, illuminated by two adjacent windows in a bay nearly the width of the room. The wall paper is a figured gray of approximately 45 per cent. reflection coefficient. The dimensions of the room are shown in Fig. 3. A long room of this type is perhaps one of the hardest to illuminate satisfactorily by daylight or artificial daylight because of its depth. One with windows on two sides would have been preferable and easier to deal with, if it had been available.

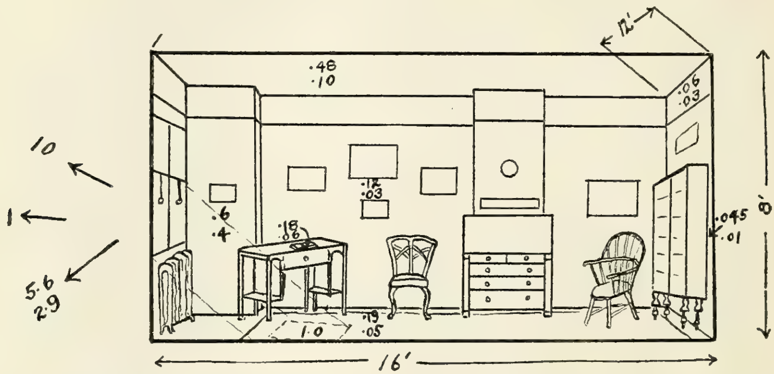

Fig. 3.—Distribution of surface brightness in arbitrary units by daylight. Large values, a case where sunlight falls on floor. Small values, sun not streaming in.

Observations, both qualitative and quantitative, made from time to time in this room, revealed some interesting points. (1) At all times, raising the shades above the middle sashes made the lighting less pleasant. (2) The room was brightest and, on the whole, most pleasing when the sun streamed in on the floor or wall and shone on the street below. (3) The effect was unpleasant when the sun fell upon the (gray stone) house fronts opposite. (4) A gray or misty day was not pleasant. (5) The distribution of illumination or brightness was such that the face of a person sitting with his back or side to the window received sufficient light from the room so as not to be in marked contrast to the background, or to have the two sides of his face unduly different in brightness.

Two sets of measurements of brightness are plotted in Fig. 3, one for the case of sunlight streaming in the window, the

other when it is on the street below, but not streaming in nor on the houses opposite. Both effects were extremely satisfactory.

An analysis of the various data has led me to the following conclusions:

The most pleasant conditions are those when the effective light source is of three parts: (1) A large area of bright sky subtending the solid angle of the window, invisible from the greater part of the room and illuminating the floor and lower part of the room. (2) A large area of intrinsic brilliancy about one-tenth that of the sky, visible from the room (houses opposite). (3) A large area of intrinsic brilliancy about one-fourth to one-fifth that of the sky, invisible from the greater part of the room, but illuminating its ceiling.

Add that these light sources are at the side, and remember that the bright sky is of much lower intrinsic brilliancy than most artificial light sources, and the complete specification of pleasant window daylight of this room becomes something like this: *illumination from large area concealed light sources at the side,* that is, just the case we have seen to be absent from prevalent lighting systems.

There must be added to this set of conditions the further one that the walls adjacent to the window must be well lighted in order to prevent excessive contrast. This is frequently accomplished by having windows on two sides. In the present case the walls adjacent to the windows are perpendicular to these and are, therefore, lighted by one set of windows.

Probably to an architect, who has made a study of window lighting, this is all an old story. It is interesting in the light of these observations to notice that low broad windows (frequently in alcoves) are becoming common in the newer houses, taking the place of the old-fashioned high narrow window, the upper portion of which sometimes cannot be used without exposing to view a dazzling patch of sky.

THE WINDOW AS A LIGHT SOURCE.

The numerical data given in Fig. 3 make possible a study of the windows of this particular room as a light source.

As viewed from a point in the room the windows present prac-

tically the appearance of two adjacent squares 30 in. by 30 in. (0.762 m. x 0.762 m.), with their centers at a height of 42 in. (1.07 m.) above the floor. As viewed from various points the angle subtended by the light source of course changes, diminishing to zero above and below and to either side. Were the landscape as seen through the window of uniform intrinsic brilliancy, then the window would be equivalent to a flat uniformly bright plate. It

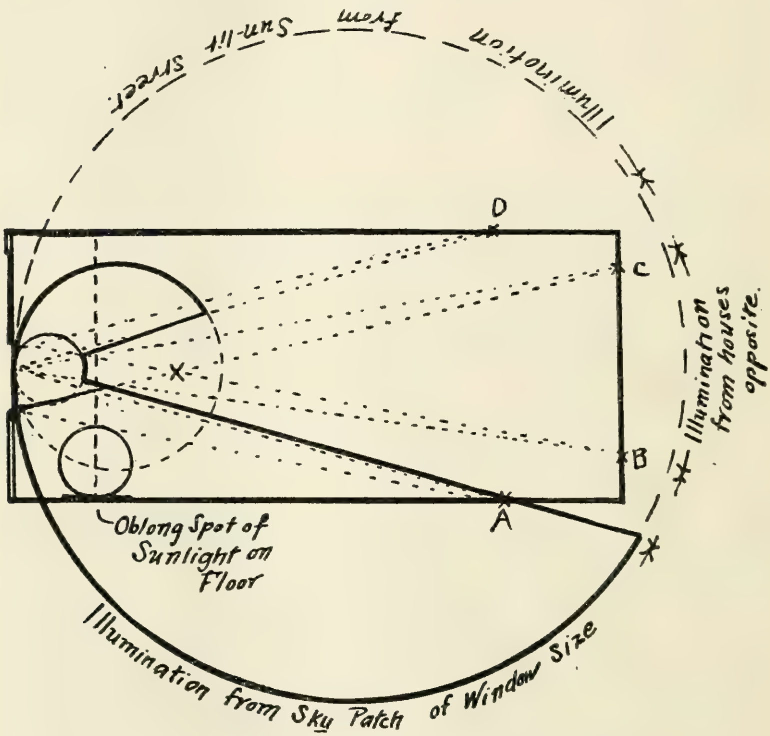

Fig. 4.—The window considered as a point source of light.

could be copied by a sheet of thick opal glass illuminated from outside, or by a diffusely reflecting surface, such as an "indirect" ceiling source turned through 90°. This, however, is not the case, except when in a high building facing the sky, or if a fog reduces all out-of-doors to a nearly uniform gray (a ratio of sky to houses of 2 to 1 was found by measurement on a foggy

day). Both of these conditions are found to be undesirable, as noted above.

In the second-story room, which was studied chiefly, the change of intrinsic brilliancy and effective area may be followed best by consulting the drawing, Fig. 4, in which the window is considered, for convenience only, as a point source of light. Starting directly below the window the illumination is from a narrow slit of the intrinsic brilliancy of the sky. As the test surface is moved away from the window this slit increases in width (as the cosine of the angle with the normal) until a point (A) well back on the floor is reached. Here the top of the houses opposite becomes visible, cutting off part of the sky. At the point (B) the sky is no longer visible and from there to the point (C) high up on the wall the intrinsic brilliancy of the window is that of the house opposite. Between (C) and (D) the street below becomes visible and from (D) over the ceiling to the window the illumination is from a patch of the brightness of the street surface. There are, therefore, to be distinguished (in this case) three different brightnesses, the distribution of illumination from each of which is represented by a circle of appropriate diameter, tangent to the window. From the brightness measurement of Fig. 3, it appears that these three circles should have diameters for the most pleasant condition of about 10-1-3, and they are so represented in the figures.

It will be seen that a seated person in almost any part of the room, looking toward the window, sees only the comparatively dull houses opposite. The floor and ceiling are illuminated by a much brighter source than the houses and act as secondary light sources of low brightness. If the sun strikes the floor the spot becomes another secondary light source. The most startling thing is the very irregular shape of the light distribution curve and its sharp transition from maximum to minimum, unequalled, I believe, in any commercial lighting unit. Were it not for the fact that the source (window) is large these sharp transitions would cause sharp contrasts of light and shadow between the portion of wall and ceiling represented at A, B, C, etc. Actually, the deviation of the window from a point source makes the transitions gradual and soft.

An interesting feature of the distribution from a window is that it tends to diminish the extreme brightness ratio. The greatest illumination is on the floor and furniture, which are almost invariably the darkest surfaces. With a uniform distribution from a side window or with many artificial systems the floor and furniture retain the normal brightnesses which their low reflecting powers give them. With windows they are made several fold brighter, which must be no inconsiderable factor in the general effect. This fact explains in part why with "indirect" systems the floor and furniture are apt to appear unnaturally dark. In order to preserve the daylight ratio of brightness above and below it would be necessary with the "indirect" system, with its bright ceiling, to exchange the floor coverings and furniture for some with at least a 4 or 5 fold higher coefficient of reflection. The excellent appearance of white tiled barber shops under the "indirect" system is confirmatory of this.

ATTEMPTS TO ARTIFICIALLY APPROXIMATE THE CHOSEN DAYLIGHT DISTRIBUTION.

The General Problem.—As an interesting exercise, attention was turned to ways and means for reproducing artificially the best daylight conditions in the room described. It soon became evident that the problem was not a simple one. It appears, in fact, that there is just one solution, and that is to reproduce entire the broad expanse of sky, houses and street. No small light source will copy all the qualities desired. For instance, while it is possible to produce at a given point in the room the general distribution of illumination and brightness given by daylight, the same lighting scheme will not produce the desired effect at another point. The problem is closely akin to that of producing a perspective drawing which would automatically change its perspective as the observer moved, or a photograph in which one could look around the corners by moving one's head from side to side. For instance, a horizontal plate placed above and outside the window would produce the desired sky effect near the window, but would fail farther back in the room. A vertical plate of low intrinsic brilliancy would take the place of the opposite houses as far as the eye of an observer within the room, but the

sweep of tenfold brighter light across the floor and the brighter light on the ceiling would be missing. As it was not possible to light up "all out of doors," several approximations to the conditions given in Fig. 3 were attempted, which are described below. The first of these may be called a lighting fixture, the others lighting schemes, or, as a non-technical visitor described one of them: "not lights, but light."

(1) *A Side Wall Fixture to Approximate a Window Effect.*—This fixture might be popularly described as "semi-indirect from the side," although it presents a number of deviations from what would be obtained by merely supporting a semi-indirect bowl out from the wall. In construction it might be most nearly described by saying it is a table lamp with the back half and top of the shade removed. In detail it consists of the light source, which should be of such form or provided with such a reflector as to throw its light chiefly below and above the horizontal about as does the prototype window curve, added to which is a large area translucent screen so calculated as to let the direct light fall upon the wall behind, the ceiling above and the whole floor of the room, and of such degree of translucency as to closely approximate the brightness of the illuminated wall behind. The device is shown in Fig. 5, where it is represented as a floor standard. From the plan and elevation it will be seen that for no normal position in the room is the bright part of the light source visible, but screen and wall form a large source of low intrinsic brilliancy. This is secured by the peculiar shape of the screen, which is concave to the light with respect to the horizontal plane, half enclosing it, but only large enough vertically to conceal the light from the occupants of the room. The screens so far made up have been covered with flowered silk, or cretonne, and lend themselves admirably to the general decorative scheme.

This fixture when used in a room having light walls (a necessary condition) gives to a large degree the desired window effect. The light is directed from the side, giving the long pleasing shadows; there is a large measure of diffusion, due to the large area of the effective source; the floor and furniture have a pleasant "sun lit" appearance. The thing of beauty is the light itself and not, as in many cases, a piece of decorative metal work,

designed to be viewed by daylight. The limitations to this device are the necessity for bright walls, which is not serious, and the fact that the direct light in the lower hemisphere cannot be made to fall as far out on the floor as with windows, without carrying the shade too far in front of the light for convenience. It does,

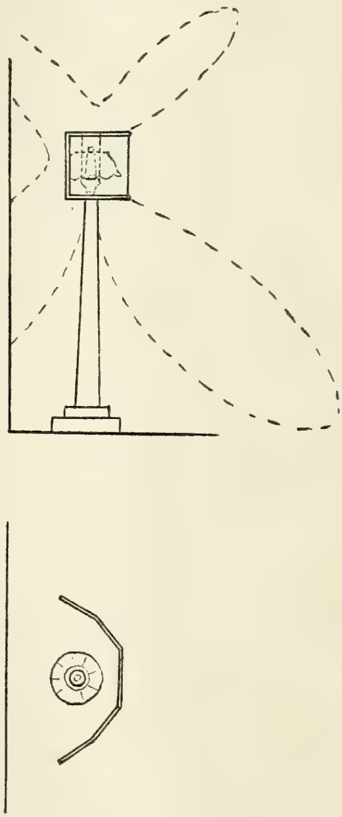

Fig. 5.—A side wall unit to approximate window conditions.

however, make an extremely pleasing light source and has, in several months of use, worn well. It is especially good if two or more are grouped at the window end of the room. It appears that the best height for these shades, if they are to be in the field of vision, is about on the level of the eyes. If a light source must be visible it seems to be less irritating at this line than at

some degrees above. It is perfectly possible to make the shades and wall behind of such brightness that a person's face may be viewed against them as a background without undue contrast.

Side wall brackets have always been popular with those who wish their faces to appear at their best. The defect of most bracket fixtures has been that the light sources have an altogether too great intrinsic brilliancy and make excessive contrast with the wall behind, especially if the latter is dark wood, as it too often is. This defect is overcome in the arrangement here described. There has thus far been no dissenting opinion as to the excellent performance of these side wall "windows."

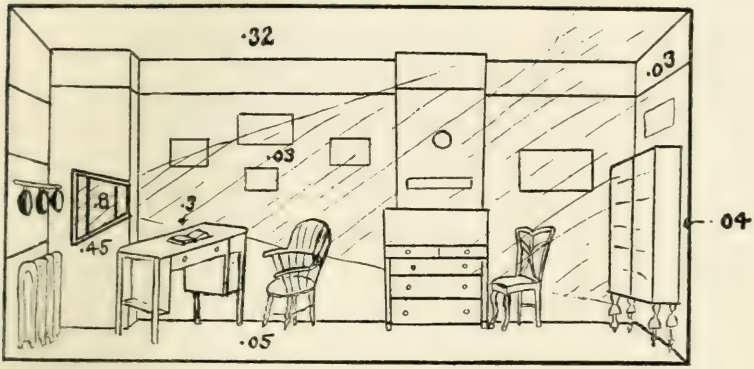

Fig. 6.—A point source copy of daylighting. (Brightness values are multiplied by a factor 10).

(2) *An Alcove Light with Semi-window Characteristics.*—This scheme was tried out after a study of the window considered as a point source as shown in Fig. 4, and was carried through in full knowledge of the fact that the characteristics of a large window could not be completely copied without a comparatively large source. The plan is shown in Fig. 6, where "A" represents a line of light sources with aluminized scoop reflectors sending a large part of their light in the lower hemisphere and approximating the lower portion of the large circle of Fig. 4. At "B" is placed a frame 15 in. x 6½ ft. covered with cretonne and muslin sheeting. This to an observer back in the room takes the place of the houses opposite, as a large area low brightness source. By trial such a thickness of fabric was found

that the illumination back in the room due to it was one-tenth that from the row of lights as seen below it from the floor, that is, the condition found best by daylight.

This installation is exceedingly interesting. With 7,200 lumens the surface brightnesses through the room measure up on an average one-twelfth that found as the average of the two daylight distributions given in Fig. 3. It was found most desirable, however, to let considerable light go to the ceiling, which gives more light in the room and approximates more to the "sunlight" case of daylight distribution in Fig. 3. This, when the eye is adapted to night conditions, is very nearly ample at every point of the room. Probably twice as much would be more than enough. The room presents a strikingly daylight appearance, except for three things, all due to the same cause. First, the line of demarcation between the light from the 'houses opposite" and the "sky" is too sharply marked on the walls; second, the specular reflections on the furniture, books, etc., near the windows, visible on entering the room, are relatively far brighter than they would be by day, as is to be expected; third, the shadows of the furniture are too sharp. These are all due to the point source character of the light, and are only to be seen above and below the parts illuminated by the cloth covered screen. The appearance is practically the same as can be obtained by covering all the windows except a narrow horizontal slit. Wtihin the angle which receives light only from the screen and from walls and ceilings, the daylight character is almost startling.*

(3) *A Window Reflector*.—The requirement of a large-area concealed light source at the side, having the distribution curve of the window as a light source, may be approximated to by combinations of optical devices, such as prisms and reflecting surfaces. One of these devices forms the last experiment to be described.

In accordance with the subject matter of this paper, it is clear that an "indirect" fixture, if directed toward the wall, would not

* If the windows be made horizontal slits of about 10 inches width and if the time of day is taken when the sun falls on the houses opposite, an extreme case of bad lighting is obtained. The illumination of the room is quite insufficient; there is a high ratio of brightness between the light source and its surrounding in the field of view; shadows are sharp and specular reflections are too bright. This illustrates clearly the importance of the light source being large and of having its brightest part concealed.

give the desired window effect because, while the light source would be large, it would be of uniform brightness as viewed from all directions. In order to secure for this experiment the proper unsymmetrical distribution of brightness, recourse was had to reflecting surfaces intermediate between specular and matt. Measurement of a number of surfaces, such as scratch-brushed aluminum, aluminum paint, mirror glass covered with transparent curtain material, etc., led to the choice of ribbed mirror glass, sandblasted on the front. Later it was found better to decrease the brightness of the diffuse component, and this was done by rubbing the sandblasted surface slightly with oil. Probably a lighter sandblasting would have given the desired quality. Such mir-

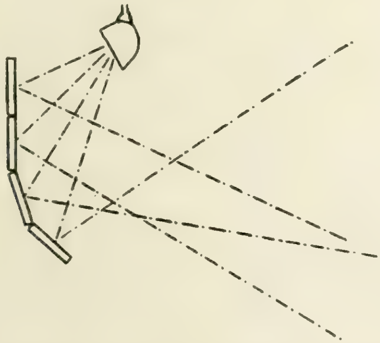

Fig. 7.—Section of special reflectors used for artificial window.

rors placed with the ribs vertical and illuminated by a light in front and above give a large semi-specularly reflected component, which is nevertheless so much diffused as to appear to come from a large area of mirror; and a small diffuse component, the ratio between the normal and reflected brightness being easily made one-tenth by tilting the mirror.

A pair of frames of these was made, as shown in Fig. 7, each frame consisting of four 7 in. by 30 in. elements. These frames were hung in the window, as shown in Fig. 8, and were illuminated by a row of small units in the aluminized concentrating reflectors used before. As shown in Fig. 7, the specular reflection from the three upper elements illuminates the floors and lower

parts of the walls of the room. The bottom elements illuminate the ceiling, taking the place of the brightly lit street pavement before.

An observer sitting in the room sees these surfaces as of a uniform low brightness. On dropping his head he begins to see the top elements brighten, corresponding to the sky appearing over the house tops. On dropping still lower, the other elements brighten until at the floor the whole "window" appears a uniform sheet of light. On standing up and approaching the window the lowest elements become bright in the same manner. This copy of window conditions is in fact very close. The reflected light is, because of the ribs and the sandblasting, excellently diffused. Shadows in the room are long and soft.

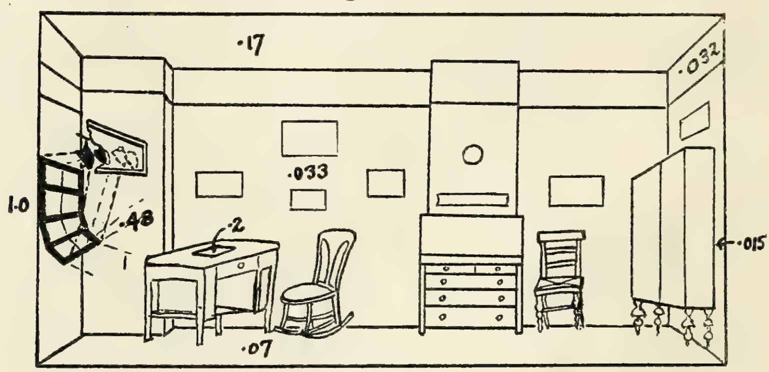

Fig. 8.—Artificial window lighting. (Brightness values multiplied by factor 10).

The excellence of the copy is shown by the relative brightness measurements. These indicate that the relative brightness of all visible objects is nearly the same as by daylight without the sun on the floor, as shown in Fig 3, the actual brightness being close to one-tenth of that of daylight. In fact this imitation of daylight distribution in the room is, from the standpoint of relative brightness, direction of light and diffusion, so perfect as to leave outstanding only the factors of actual intensity of illumination and color of light.

Good and Bad Features.—This reflector scheme has many elements of merit. It is in some respects almost uncanny, especially to one not looking toward the imitation windows. The sweep of light over the floor; the illumination of the low por-

tion of the walls; the brightness ratio between ceiling and floor are most striking and very different from the usual artificial light conditions. But the general effect is not pleasing. There is a harsh "contrasty" effect. The darker end of the room looks too dark; the windows too light; shadows are too inky black. The effect is very much like a foggy day, or as though the houses opposite were brilliantly sunlit. Why is this? In some part to mental bias, perhaps; the windows do not look just like real windows and one is strongly conscious of the fact. Also the fact that the light source is near, instead of distant, and that our ocular muscles of accommodation are quite conscious of the real state of affairs. The explanation of the greater part probably lies in two facts: first, the absolute intensity is too low, and, second, the color of the light is not white. The absolute intensity is about one-tenth daylight intensity. My observation leads me to believe that a given physical ratio of brightness becomes subjectively greatly increased when the order of illumination is decreased as much as it is here. If a ratio of brightness of 10-1 for different points in the room is satisfactory by daylight then with 1-10 that illumination this ratio must be decreased to 5-1 or 3-1. With this low order of illumination the shadows, such as those on the room side of the face, are so dark as to appear nearly black; the high-light side alone is seen. By the greater light of day, although the relative brightness of the two sides of the face is the same, the dark side is bright enough to be easily seen; the bright side does not appear too bright. I can best describe the phenomenon by saying that the room under this 1-10 illumination looks like an under-exposed photograph—the high lights alone come out. By exposing longer a good negative is obtained; by increasing the illumination tenfold, I believe—unless the color difference has a great deal to say—that this copy of daylight would be "the real thing." Physically it measures up in the right proportion. Subjectively the proportion becomes distorted. I have found support for this idea by the experiment of wearing dark glasses of 1-10 transmission in this room when the daylight conditions are good. The conditions become trying at once. What is called for in the present case is an increase in total light, which cannot be made in the existing house installa-

tion without danger. Incidentally it may be remarked that this accentuation of contrasts merely means a larger value for the Fechner fraction at low illuminations, which is actually found by experiment.

The general effect in the room is enormously improved by adding the light from two side wall table lamps described above, placed in the corners next the alcove. These give somewhat more light, but more than that, they throw their added light upon the ceiling and side walls without increasing the brightness of the "windows." These latter cease to be too bright; the shaded side of the face becomes visible and a first rate effect is produced.

On turning off the window light alone the room seems to jump upward, showing very prettily the importance of the daylight effect of the sweep of light on the lower part of the room. I believe this window experiment would have been more successful had the room been provided with an artificial window at the side. A long dark room such as this is difficult to light by day; were it not on the south side of the house I believe it might be a failure. It certainly represents an extreme type. I am inclined to think another type of room say a broad shallow one furnished with these artificial windows might be quite successful, even without an increase in the light.

The color of the light may have something to do with the harsh effect. As above noted blue light scatters much better than yellow. A photograph by ultra-violet light will show almost no shadows owing to scattered light from the dust particles in the air, while in infra-red light shadows are black. Something of this sort may contribute to the inadequacy of this artificial window.

SUMMARY OF CONCLUSIONS AND SPECULATIONS ON ROOM LIGHTING BY LARGE AREA SOURCES.

Several conclusions which seem to be justified by these various experiments, are given as follows:

The desirable qualities sometimes found in window lighting by daylight are, (1) direction from the side; (2) soft shadows and low intensity of specular reflection, due to the large size of the source; (3) the direction of a large part of the light on the lower,

usually the darker, parts of the room, and (4) the concealment of the principal light source.

It appears possible to make a very close physical copy of the window as a light source whereby all the characteristics may be duplicated. An attempt to do this shows that to the above qualities must be added (5) large quantity of light as compared with what is usually available from artificial sources. It is suggested that this is less necessary if the artificial windows are placed so as to secure a more uniform distribution of illumination than is necessary by daylight.

These various qualities can be separated to some extent into necessities and luxuries; some are necessary for comfort, others appeal to the esthetic sense. I believe that in concealment of the light source, so that it is not the brightest object visible, in making it of large area and in introducing a certain amount of side light from large area, very low intrinsic brilliancy sources, most of the really necessary and many of the attractive characteristics of daylight may be obtained, with much lower intensity and, consequently, lower cost than a true copy of daylight would come to. I favor a combination of deck lighting for general floor and working plane illumination, with side wall lights of the type described above. I hope to report on an installation of this type at some future date. If the room is not too large nothing at present promises to excel the side wall window brackets of Fig. 5.

THE COST OF COPYING DAYLIGHT.

If it were not for the prohibitive cost of an exact copy of good window daylight, it would be a very desirable thing. This paper may be concluded with a calculation of just what this cost is.

The room experimented with has an area of 200 square feet, 1,600 lumens were used and ten times that were required, or 16,000. Suppose absorbing screens were used to make this light of daylight color; this would call for about ten times the amount of light, or 160,000 lumens generated. Taking the tungsten lamp at 1.5 watts per spherical candle as the light source, one watt per square foot is actually used, ten watts is called for, one hundred if subtractive daylight is made (or 20 kilowatts for the room).

Let us finish, however, with a little speculation and prophecy.

I have shown elsewhere* that if we could produce white light with no accompanying invisible radiation or other losses, by some merger of fire-flies, there should result an efficiency of 330 lumens per watt, or about 40 times that of the tungsten lamp. Since 16,000 lumens is necessary to produce daylight intensity and distribution in this room, there would be required for this ideal white light $\frac{16,000}{300}$, or about 50 watts. This, it is interesting to note, is just about what the builder of the house has provided for in the low-hung, glaring and utterly horrible central fixture. Artificial daylight may not always be a luxury.

DISCUSSION.

PROF. GEORGE A. HOADLEY: It seems to me that Dr. Ives has given us in the paper which is before us an excellent example of how to carry on laboratory experimentation in our own homes.

It is true that the subject under consideration lends itself more than some others would, to such investigation but there are many phases of the problems of lighting that require just the kind of semi-leisure investigation that can be carried out at home during the long winter evenings.

Each problem that comes up in the lighting of our homes is different from that which presents itself to our neighbor. They all have, however, one common property, they are intensely practical problems and if successfully solved will tend to secure greater comfort and economy.

I fully agree with Dr. Ives in his contention that large light sources are the most desirable. In order to secure such a source in my dining room, I made a simple change in the fixture that has proved to be most satisfactory. The lamp shade was of fluted glass dark green on the outside and white on the inside, giving a good downward diffusion. Its location was too far from the ceiling and the light from the lamp shone directly in the eyes of those sitting at the table. By the insertion of a ground glass disk in the shade holder below a globe-shaped lamp, the light comes from the area of a circle fourteen inches in diameter, gives uniform diffusion and no glare.

* *Electrical World*, June 15, 1911.

Dr. C. E. Ferree: I have seen the devices described by Dr. Ives, and I agree with him, so far as my present knowledge of the subject goes, on all the essential points of his discussion. The table-lamp shade seems to me to be especially good. It is in principle, I think, the best device of its kind I have yet seen. Among other features it possesses the advantage of shielding the eye from the source of light without interfering with the distribution in any other direction. A shade of this kind should not only give excellent results for desk and table work but it can be used very successfully for the illumination of a room. Its degree of opacity, its distance from the light-source, and the distance of the light-source from the reflecting walls of the room, can all be so regulated that a fairly high degree of uniformity of general illumination can be obtained,—very much more uniform than is usually obtained from fixtures of the semi-indirect type.[1] The table-lamp has, moreover, so far as the eye is concerned, an advantage of position over the ceiling fixture, or a wall fixture at the height at which wall fixtures are usually placed, because it can be kept more nearly at the level of the eye. That is, if we are to have the source of light in the field of vision at all, it is better to have it as nearly as possible at the level of the eye, for the image of the source when it falls on the retina in its horizontal meridian produces less discomfort than when it falls in the vertical meridian. When used as a desk-light I think the shade should be made more opaque than when used for the general illumination of a room, because when working at a desk the lines of sight are directed downwards and a shade of the degree of transparency used by Dr. Ives would permit more light to fall on the sensitive lower half of the retina than should be the case if the maximum degree of comfort is to be attained. With a shade of the dimensions used by him probably the most favorable distribution of light over the retina can be secured by making the shade completely opaque. The condition to be attained is that the illumination of the retina shall fall off more or less uniformly from center to periphery.

[1] The classification of this shade as semi-indirect in type is somewhat arbitrary. Dr. Ives may very well prefer to call it indirect since by a proper regulation of the opacity of the shade, distance from the wall, etc., the light in the immediately surrounding field may be made approximately equal in intensity to that at the source.

In securing this condition the factors that must be taken into account and regulated in this case are obviously opacity and breadth of shade, direction and distance from the eye, position in room relative to reflecting walls, etc. The shade in principle permits and in fact needs more or less special regulation for each individual case.

I found the light from the inverted umbrella uncomfortable to the eye, and from the similarity of the distribution given by it to the distribution given by systems we have already studied, I would conjecture that the eye would also fall off considerably in efficiency when working under it. With regard to this light, the following points may be noted. (1) The distribution given by it is semi-indirect in type. In our work on distribution we have found that the eye falls off in efficiency almost as badly under the semi-indirect systems as under the direct. (2) It is a ceiling light and because of the low ceilings found in most dwellings it would have to be placed at a height above the level of the eye that would be very uncomfortable. As it is installed in Dr. Ives's home, its angle of direction from the eye is very near to that which we have found to give the greatest discomfort. (3) The light is rendered yellowish by transmission through the shade. So far as our work on the effect of quality of light on the eye has been carried, we have found greater loss of efficiency and more discomfort under yellow light than under lights whiter in quality. (4) Sufficient diffusion is not produced by the umbrella as a shade to break up entirely the images of the light-source.

Dr. Ives's photometric analysis of the distribution of light in a room illuminated by daylight from windows is interesting and very suggestive as to methods of attack on the problem of lighting. His device to reproduce this distribution for artificial light I find, however, to be very uncomfortable to the eye. This difference in effect on the comfort of the eye presents an interesting problem for solution. Dr. Ives states that he has reproduced by means of his artificial window, at a lower scale of intensity, the relative distribution of light in the room gotten from the daylight window. That is, the ratio of intensity of light at the source to that at various points in the surrounding

field was made the same for both cases. From the standpoint of the light in the room, then, the only difference between the two cases is in terms of his statement apparently in the quality of light and in the scale of intensity used. This difference, I understand, is believed by Dr. Ives to be the cause of the difference in the effect on the comfort of the eye. I should not myself be inclined fully to accept this explanation until more differential evidence is obtained. The effect of both factors in question can be investigated under conditions in which it is more definitely certain that no other factor is present. For example, the effect of quality of light on the comfort of the eye can easily be tested out by separate experiment, also the effect of changing the scale of intensity when a definite ratio of intensity between a given light-source and the surrounding field is maintained. I hope that later both of these points will be investigated. On the latter point I have at present this much evidence to offer. When working with either a direct or semi-indirect system of lighting, the eye both falls off less in efficiency and experience less discomfort at the lower scales of intensity than at the higher. The most favorable intensity too is found to be less than that attained by Dr. Ives with his artificial window. If it can be assumed, then, that the ratio of intensity of source to surrounding field in our work remained approximately constant as the general scale of intensity was changed,[2] as I have every reason to believe it did, the above results would lead, so far as the case is representative, to a conclusion which is just the reverse of that suggested by Dr. Ives in partial explanation of the excess of discomfort caused by the artificial window. I would in fact myself be very much inclined to seek further for a factor in the cause of the discomfort. Dr. Ives secured his distribution by a number of reflecting plates set at different angles with small spaces between. The reflection from these plates was, moreover, only partially diffuse. To the eye in any given position, the surface brilliancy of the plates was not by any means uniform nor even uniformly graded from point to point. Quite

[2] In these experiments clear tungsten lamps ranging in wattage from 15 to 100 were used. In each test the wattage from fixture to fixture was uniform, *i. e.*, the lamps in all the fixtures were either 15's, 25's, 40's, 60's, or 100's, depending on the intensity desired.

considerable specular reflection and glare were present. Viewed by the eye in any given position, the window had more or less the appearance of several light-sources of different intensities. The surface brilliancy of a window illuminated by daylight seems on the other hand, to the unaided eye at least, to be more uniform, or at least more uniformly graded. The surfaces that reflect the light into the room, corresponding to Dr. Ives's plates, —the sky, the pavement, the walls of neighboring buildings, etc., are in general not in the field of vision or at least not so largely in the field as are Dr. Ives's plates. Moreover, the reflecting surfaces which are in general concerned in the illumination of a room by daylight give diffuse reflection and not specular. In short, it seems that something that affects the comfort of the eye has escaped Dr. Ives in his photometric analysis of distribution. Whether or not it is something that could be detected by photometric analysis I am not prepared to say. It would seem to me, however, that if an adequate check were to be had in both cases on distribution of light in the room and of surface brilliancy in the source, readings would have had to be taken in a greater number of directions than were taken by Dr. Ives. That is, it seems to me possible to have duplicated by means of reflecting plates, especially plates which were not completely diffusely reflecting, set at appropriate angles, the readings in the number of directions he employed and still not have had a distribution and surface brilliancy by any means identical with that present in his illumination by means of the daylight window.

Dr. H. E. Ives (communicated): Upon seeing the amplified discussion which Dr. Ferree has submitted in writing, I feel it encumbent on me to describe more in detail some of the experimental conditions and correct what I believe are misconceptions on his part. In general Dr. Ferree believes that the third copy of daylight described is not as complete as the paper would lead one to believe,—that differences are present that escape the photometer. I think that Dr. Ferree has not properly grasped the fact that the measurements given are not of illumination, but of surface brightness. Thus, when he speaks of the "most favorable intensity," as determined by his own experiments, being less than that of these experiments, he can be giving only an esti-

mate of intensity of illumination, since the intrinsic brightness of the direct and semi-indirect units being studied by him is tens or hundreds of times greater than the brightest visible object in the window experiment. In fact, so extremely different in magnitude and distribution are the visible bright areas in Dr. Ferree's experiments and mine that it appears to me out of the question to attempt any comparison based on a mere guess at the relative illuminations. Considerable stress is laid by him on the "specular reflection" of the plates constituting the artificial windows. My description of these as partly specular was unfortunate, as it gives the idea of reflected images. A better description would be "matt reflecting surfaces of varying reflection coefficient in different directions." The sandblasted mirrors as used give reflected "images" of perhaps one foot diameter. The light sources were six inches apart; consequently it is easily possible to arrange these reflectors to present a surface entirely uniform in brightness. It is physically impossible, when care is taken to secure perfect uniformity of reflecting power in the various elements, to distinguish by inspection from any given direction that the reflection is not perfectly matt.

It is quite true that the different sheets were not uniformly bright, but this was because before Dr. Ferree saw the installation absolute uniformity was tried out and found far more trying to the eye than a certain amount of irregularity, which was, therefore, allowed to creep in. This latter is decidedly less than that present by day in the landscape seen through the window.

I, therefore, hold to my claim that the conditions produced were a very accurate copy of the daylight conditions and appearance, with the exceptions noted, namely, the proximity of the bright surfaces, the low absolute intensity and the color of the light. I entirely agree with Dr. Ferree that these factors ought to be tested out separately to determine their relative importance. We look to the psychologist to do this.

MR. ROBERT B. ELY: Decorators have, in numerous instances, used cretonne screens on candles in dining rooms and bed rooms, etc., so constructed as to reflect the light on the wall, the shades being elliptical in shape and so placed as to conceal the light

source from view. In a great many of these instances I have found that there has been complaint of poor illumination in the center of the room with the candles equipped in this manner. In bed rooms this has been overcome by placing two small portable lamps equipped with shades on bureaus or chiffoniers, so that the light was reflected from bureau scarf to illuminate the face of the person standing in front of the bureau or chiffonier. In dining rooms it has been necessary to resort to the use of a candelabra, equipped with imitation candles and suitable shades.

MR. R. L. LLOYD: It seems to me the natural direction for light is from overhead. We are living under artificial conditions in houses with windows in the side walls, and have become accustomed to seeing light enter that way, but the natural tendency will generally be found to be to turn one's back to the light, so as to keep it out of the eyes. When the Ancients first began to utilize artificial light they turned naturally toward locating it above, and I understand that some of their temples were made without roofs, so that light could enter in the natural direction.

Although these experiments of Dr. Ives are valuable as researches in science, I think he is working in the wrong direction, in trying so assiduously to imitate lighting as entering from windows, when it would be much more easily accomplished to arrange the light to come from above. We have seen by the demonstrations of Mr. Luckiesh and others that when the light is directed on natural objects from above, we see them in their natural appearance, and that when the light is directed from other than above, their appearance is distorted. The photographer too has learned this, and always makes use of a skylight in his studio for taking pictures.

As stated before, these experiments of Dr. Ives are very interesting and are valuable contributions to our science, but I have yet to be convinced that a simulation of artificial conditions is a proper one for the best results.

PROF. A. J. ROWLAND: I have had the privilege of seeing the installation of lights and lighting referred to in Dr. Ives's paper. I must confess to a certain first sense of bewilderment when I saw Dr. Ives's installation, especially that for producing day-

light values. I am so used to seeing lights in certain places, mounted in a conventional way, that I have pretty strong feelings about something special or unusual. The simplicity of the side wall lighting scheme, and the good results secured from it, impressed me strongly. When it can be used intelligently, it seems to me to be one with points of great merit. The trouble with most plans which secure good lighting by the use of things outside the lighting fixture itself as a source, comes from the extraordinary way in which applications are made by light users. Dr. Ives's walls are covered in such a way that they lend themselves splendidly to use as secondary light sources. At my home a deep green felt paper would make the plan worthless. I wonder whether in ordinary service most people would not swing the shade 180 degrees from its proper position and utterly spoil the lighting scheme. I like the large source plan; I like the idea of placing the main sources of light on levels similar to those from which daylight is derived; and the simplicity of the whole side lighting plan has much to commend it.

In connection with the paper, the term "brightness" has been used a number of times. I think it is one which needs to be explained carefully. If one compares the brightness of a white wall a gray wall, or a dark colored floor, it is a thing independent of color. Just what does it imply? How is it to be measured?

Mr. Charles O. Bond: The semi-indirect side-wall lighting scheme proposed and favored by Dr. Ives deserves particular attention. He shows that strong contrasts in the field of vision are avoided; that the method lends itself to artistic treatment and adornment of a room into which even color variations may be introduced; and, best of all, the method has "worn well."

His data have been obtained in a home, and in such conditions fixed positions are not compulsory. If the lighting is found trying while one is occupying one seat, it is easy to change to another. That is one reason why such indefensible lighting prevails in many houses.

The side-wall semi-indirect method ought to be easily adaptable with greatly increased resultant comfort to small audience chambers, such as church parlors, where persons may not easily change the lighting conditions through a change of seat.

Dr. H. E. Ives (In reply): I have nothing to add to the discussion. My hope is that this paper may direct thought to certain other possibilities in lighting than are now—due to efficiency considerations—most common.

GASLIGHTING IN AN EXHIBITION HALL.*

BY ROBERT F. PIERCE.

Synopsis: The following article describes a temporary semi-indirect gas lighting installation which was provided for an exhibition hall. Ten lighting units, each consisting of fifteen upright burners within an ornamental glass bowl mounted on a pedestal, furnished the illumination. The illustrations show the plan of the unit, a diagram and a night view of the interior.

The illumination of Taft Hall in the Auditorium Armory, Atlanta, Ga., is the result of a number of compromises with more or less unfavorable elements, rather than the unrestrained working out of a consistent and coherent plan, and must be judged in the light of the existing circumstances. The lighting was primarily designed for use in connection with the convention of the National Commercial Gas Association. The same room was to be used for the beefsteak dinner with which the convention was terminated, and, in addition to this, it was desired to furnish a lighting system which should be available for the automobile show which preceded the gas convention.

The problem then resolved itself into meeting, as well as possible, the requirements imposed by each of these widely varying purposes with one installation. Naturally, it was desired that the installation embody unique features—at least, features unique as far as gas lighting is concerned—and it was suggested that indirect lighting be employed in connection with pedestals; something along the line of the installation in the Louis XVI dining room in the Congress Hotel, Chicago.

It so happened that the room was peculiarly adapted to the support of the lighting units on columns or pedestals. In fact, this was the only feasible arrangement. The ceiling is plain and unbroken, except by four beams which divide off a large square in the center of the ceiling comprising nearly one-half the ceiling area. This square is further sub-divided by a single longitudinal beam of the same dimensions as the others. Obviously the ceiling presented no location for the suspension of fixtures.

The side walls were devoid of pilasters or similar features to

* A paper read before a meeting of the New York section of the Illuminating Engineering Society, January 9, 1913.

which wall brackets might have been attached, and the only remaining expedient was in the use of columns for the support of the lighting units.

For the lighting of the hall for convention purposes, the best arrangement of the columns appeared to be as shown in Fig. 5, marking off an area bounded by the supporting columns and fronting upon the rostrum from which the convention was conducted. This arrangement also served very well for the lighting of the automobile show, the booths being arranged in such a manner that the lighting columns marked the rear corners of the booths when viewed from the middle aisle, and the front corners when viewed from the side aisles.

In the design of the lighting columns, it was considered desirable to depart from the Ionic order of the supporting columns for two reasons. In the first place, the use of similar columns would have given them the appearance of being original structural members, decapitated for the purpose of bearing the lighting units, whereas, it was felt, a different treatment would separate the lighting columns into a distinct system, having its own reason for existence. In the second place, it was desired to utilize a design which would not be out of place in other surroundings, as it was likely that the installation would be sold for other purposes after the convention. The composite Corinthian order was selected as having the widest field of possible future applications and one which would harmonize fairly well with any classic interior.

In the design of the light distribution the direct, semi-indirect and indirect systems received consideration. The latter, originally suggested, had a number of serious drawbacks. Any system of illumination which turns the room optically upside down by reason of reversing the natural order of intensities increasing from the ceiling downward, is certain to be a source of more or less definite annoyance, especially where the attention of the occupants of the room is not apt to be concentrated upon work which distracts their attention from the abnormal distribution of illumination in the room. This objection might be of little moment in a room devoted to clerical purposes, but in the hall under consideration, was held to be of much importance. The

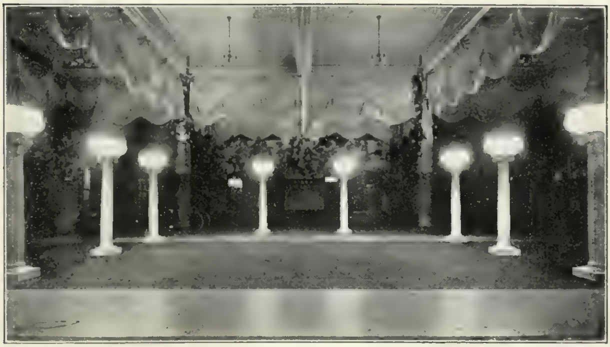

Fig. 1.—View of interior of hall.

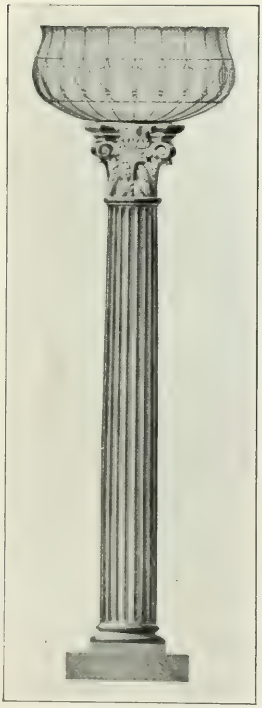

Fig. 2.—Design of bowl and pedestal.

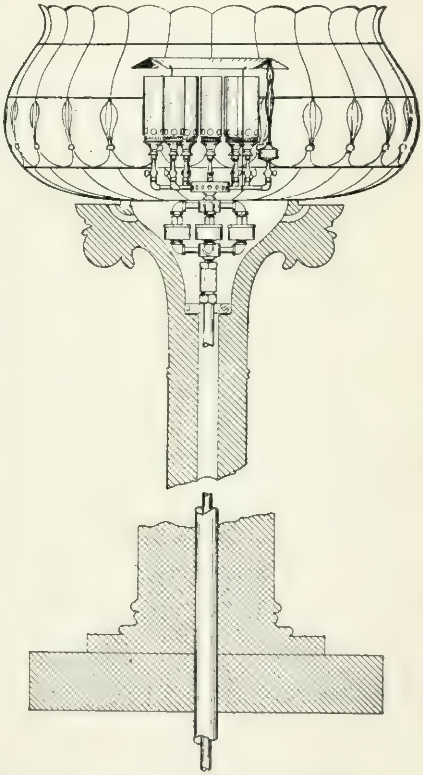

Fig. 3.—Plan of light unit, showing arrangement of lamps.

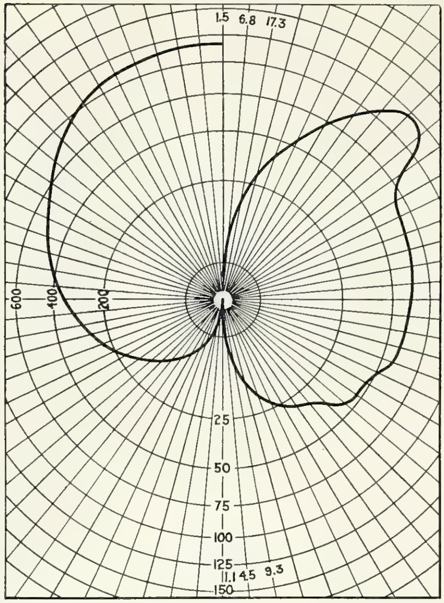

Fig. 4.—Distribution curve from light unit. In the above distribution curve the radii vectores of the right-hand curve represents the fluxes in zones extending 5 degrees on either side of the designated angle, while those of the right-hand curve represent the total flux from zero to the designated angles.

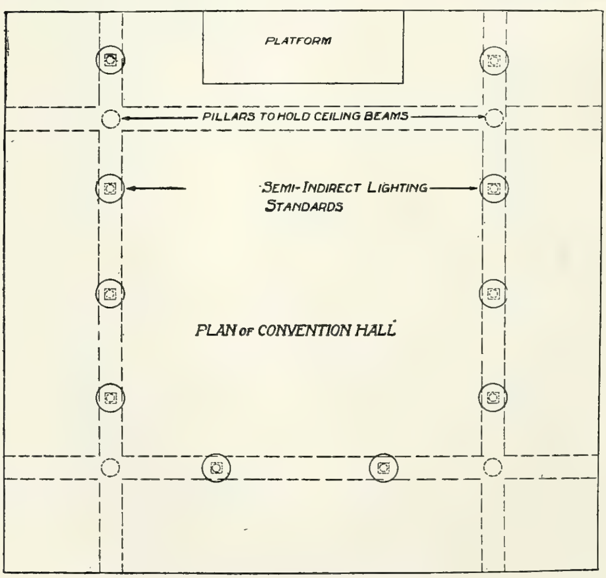

Fig. 5.—Plan of interior of the hall.

absence of an apparent source of light was deemed a considerable drawback to the indirect system from a similar consideration. Furthermore, only the presence of a luminous light source could, from an esthetic standpoint, provide any excuse for the existence of the lighting columns.

For the lighting of the automobile show it was felt that the presence of luminous light sources was especially desirable, as the appearance of an abundance of light seems to be an indispensable feature of exhibitions of this kind.

The foregoing considerations seemed to narrow the choice to the selection of either direct or semi-indirect lighting.

For the automobile show, an illumination of about 8 lumens per square foot was deemed desirable on account of the light-absorbing qualities of the black car-bodies. The area of the hall (about 5,900 square feet) demanded, therefore, a horizontal component of about 47,000 lumens, which demanded, at a utilization efficiency of, say 40 per cent. (the walls are dark green in color) about 120,000 lumens generated. It seemed desirable to limit the number of lighting units to ten in order that they might not interfere with the best use of the floor space. This demanded the production of 12,000 lumens per unit. One candle-power per square inch was decided upon as an upper limit for the specific intensity of the bowls or globes. This would have required a globe of a size altogether out of proportion with the columns, and it was finally decided to use semi-indirect lighting.

An indirect component of 50 per cent. was decided upon as meeting the various requirements to the most satisfactory degree. This ensured the reduction of shadow contrasts to a point well within the requirements of the automobile show, where ample diffusion of light for the inspection of machine interiors was required and at the same time avoided the "flatness" which would have accompanied a much lower indirect component. It was believed that the 50 per cent. direct component would be sufficient to bring the apparent plane of highest illumination well down toward the floor, where it belonged.

A light distribution (Fig. 4) was finally decided upon having an extensive character above the horizontal, with a maximum at 135 degrees. With the units as located, this provided sub-

stantially uniform ceiling illumination, preserving the flatness of the ceiling. The ceiling being a very light cream in color, it was assumed that about 50 per cent. of the light from 110 degrees upward would be effective on the working plane, giving about 30,000 effective lumens from the ceiling. Assuming 70 per cent. as the effective angle below the horizontal, 30,000 lumens would be contributed to the working plane direct from the lamps, giving an average effective illumination of about ten lumens per square foot—about 50 per cent. of which is indirect.

The bowls were primarily designed to furnish this curve by reflection from the glass itself, and to harmonize the form of the bowl with the column, it was treated as a conventionalized floral form, borne by the conventionalized tree trunk and foliage which comprised the shaft and capitol of the columns. For this reason, it was necessary to depart from the strictly classic orders in designing the bowl. Equalite glass was selected for the bowl on account of its shell-like texture and selective absorption, giving a warm lively glow in the more transparent of the irregular striations of its structure. This relieved the cold, severe white of the denser portions without conflicting with the material of the columns, which was a concrete composed of cement and marble dust. The necessity of avoiding colors in the bowl itself imposed the use of conventionalized floral forms for decoration which should be devoid of any suggestion of color, and the lotus was selected for this purpose as harmonizing both in form and color with the bowl. This might be criticised as an injudicious admixture of Greek and Egyptian orders, but it was felt that such criticism is captious, there being no necessity for adhering to purely geographical distinctions in this instance. The design of bowl and column finally selected is shown in Fig. 2.

Fig. 1 was made from a photograph of the completed installation and conveys a fair idea of the distribution of illumination. It appears from this picture that the indirect illumination is rather overdone. The dark floor, however, contributed a great deal toward this impression.

It was exceedingly unfortunate that the ceiling fixtures and draperies could not have been removed. They were extremely offensive and marred what would otherwise have been a quite

agreeable interior. It was also unfortunate that the interior could not be redecorated in such a way as partly to correct for the inversion of illumination intensities by a compensating color gradation. Had this been possible, however, it is doubtful if it would have availed much with the high intensities made necessary for the lighting of the automobile show.

Fig. 3 shows the arrangement of lamps in the bowls. Fifteen upright burners are mounted in two concentric rings and supplied with gas through magnet valves. Ignition is accomplished by a flash pilot, throwing a jet under an inverted annual trough above the burner chimneys. This pilot is simply an automatic open-flame lighter, or Boston cock, which is lighted by a make-and-break spark—an arrangement familiar to everyone who has used open-flame gas burners.

The entire burner arrangement is composed of standard parts and appliances which have been used for many years with entirely satisfactory results, so that this installation is in no sense a special one without commercial utility, but exemplifies possibilities in the way of securing unique and pleasing effects which may be utilized by any designer of gas lighting installations who cares to avail himself of them.

METAL REFLECTORS FOR INDUSTRIAL LIGHTING.*

THOMAS W. ROLPH.

Synopsis: After brief introductory comments on the progress in industrial lighting, the author of this paper presents a classification of metal reflectors and a discussion of the nature of reflection. For the most part, the paper is devoted to the merits and demerits of porcelain-enamel and aluminum-finished steel reflectors and a consideration of the distribution characteristics which influence the selection of the different types of these reflectors for industrial lighting installations. The cost of reflectors, the author states, is of minor importance in that it is readily compensated for by effective illumination when the lighting system is properly designed.

Up to the present time, the progress of industrial lighting has followed the progress of lighting in the general field. In efficiency, in variety and excellence of distribution, in diffusion and in eye-protection, the improvement of reflectors for use in the general lighting field has preceded the improvement of industrial lighting reflectors. We have now reached a point at which this condition is likely to change. Industrial lighting is assuming a greater importance and it is not at all improbable that some of the most noteworthy advances in illuminating engineering in the next few years will originate in this field. The reason is not hard to find. This is a commercial age and whatever can be reduced to dollars and cents will receive the maximum amount of attention from the business men of the country; wherever improvements can be shown to affect profits most vitally, there improvements will be most rapid. In the lighting of factories, good lighting—meaning adequate intensity of illumination, proper protection of the eyes and a high illumination efficiency—can be shown to affect profits more directly and to a greater degree than in the general field of commercial lighting.

Those interested in the advancement of industrial lighting have before them the task of disseminating among a large body of variously employed individuals the underlying principles of good illumination. Factory engineers and managers, who as a class have already shown their appreciation of good lighting,

* A paper read at a meeting of the Philadelphia section of the Illuminating Engineering Society, May 16, 1913.

salesmen who sell all kinds of reflectors, bad as well as good, gas and electric companies' solicitors, who are expected to sell results in illumination as well as gas or electricity; all these should have a clear understanding of what constitutes good illumination and of how reflectors control light in producing it. The proper redirection of the light of the lamp by means of reflectors is essential to good lighting. A knowledge of the merits and demerits of the reflectors available for factory lighting is, therefore, of particular importance.

Metal reflectors for industrial lighting may be classified as follows:

- Metal Reflectors
  - Material
    - Steel
    - Brass
    - Aluminum
  - Character of Reflection
    - Specular
      - Polished metals
    - Spread
      - Rough metal surfaces
      - Applied aluminum
    - Diffuse
      - Porcelain enamel
      - Paint enamel
  - Shape
    - Deep bowl
    - Shallow bowl
    - Shallow
    - Angle
  - Distribution of Light
    - Extensive
    - Intensive
    - Focusing
    - Distributing
    - Asymmetric

The metal most widely used, and rightly so, is steel. It is durable, reasonably low in price and readily takes an applied finish of almost any character. Brass and aluminum are both more expensive than steel and somewhat less durable. Brass finds a limited field of usefulness in reflectors of such shapes that cannot be drawn or spun of steel. Aluminium has a slight advantage because it is light in weight and its surface, when not polished, is excellent from the standpoints of efficiency of reflection and character of illumination produced.

The character of reflection obtained from a metal reflector is very important in determining the value of a reflector. By

character of reflection is meant the character of the action of the surface upon each minute pencil of light-rays, *i. e.*, whether it reflects the pencil regularly changing its direction only, or whether it breaks up the pencil, reflecting light in many different directions. There is a very general lack of understanding of these actions. The law that the angle of reflection is equal to the angle of incidence, *i. e.*, that a light-ray is always reflected at the same angle with the surface as the angle at which it strikes (Fig. 1-a), is given credit for a much wider field of usefulness than it really has. This law holds for every reflection of an individual light-ray by an infinitesimal portion of a surface; but many surfaces are rough and many other surfaces allow light to pass into them and be reflected from particles beneath, so that light-rays which are parallel when striking a surface, are often broken up and reflected in many directions.

Reflecting surfaces in common use may be grouped into three distinct classes, according to the manner in which they reflect light. These three varieties of reflection are specular reflection, spread reflection and diffuse reflection. Fig. 1 shows the character of each of these. In each case, the dotted line surrounding the reflected rays, is what might be termed the photometric curve of the light reflected from any point on the surface. Specular reflection rigidly follows the law that the angle of reflection is equal to the angle of incidence. The reflecting surface is smooth and the reflected ray always makes the same angle with the surface as the incident ray. In spread reflection the maximum candle-power of reflected light is in the same direction as in specular reflection. The light is broken up, however, and slightly spread from the direct path. In diffuse reflection the angle of incidence has no effect upon the reflected light. No matter at what angle the light strikes the surface, the maximum reflected ray is normal to the surface and the light is reflected in all directions in accordance with the well-known cosine law. The photometric curve of each point on the surface is a tangent circle. Fig. 2 illustrates the manner in which each of these three kinds of reflection is produced by the infinitesimal portions of the surfaces. Regular reflection is produced by any smooth opaque surface. Mirrors and polished metals produce regular reflection.

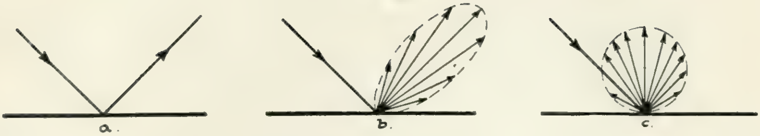

Fig. 1.—Character of reflection obtained from various surfaces.
(a)—Specular reflection; (b)—spread reflection; (c)—diffuse reflection.

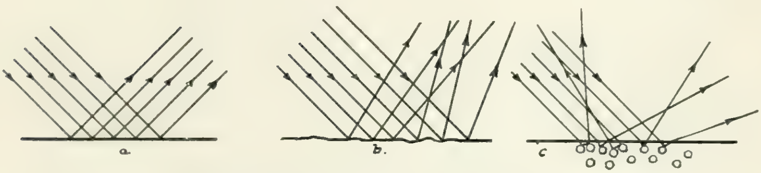

Fig. 2.—Reflecting action of various surfaces.
(a)—Regular reflection; (b)—irregular reflection; (c)—sub-surface reflection.

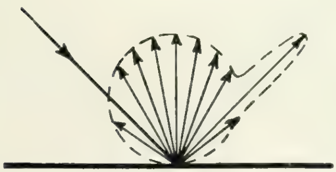

Fig. 3.—Combination of diffuse and specular reflection.

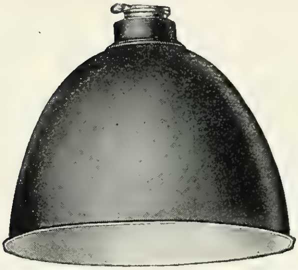

Fig. 4.—Extensive aluminum finished steel reflector. (Photometric curve shown in Fig. 5.)

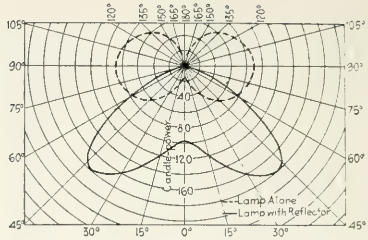

Fig. 5.—Photometric curve of extensive aluminum finished steel reflector, with 100-watt clear tungsten lamp operating at 1.13 watts per candle. (Reflector is shown in Fig. 4.)

Fig. 6.—Shallow type distributing steel reflector, porcelain enameled. (Photometric curve shown in Fig. 7.)

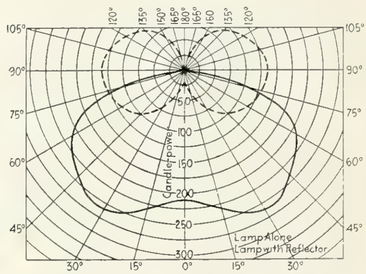

Fig. 7.—Photometric curve of shallow type of porcelain enameled steel reflector with 150-watt clear tungsten lamp operated at 1.13 watts per candle. (Reflector shown in Fig. 6.)

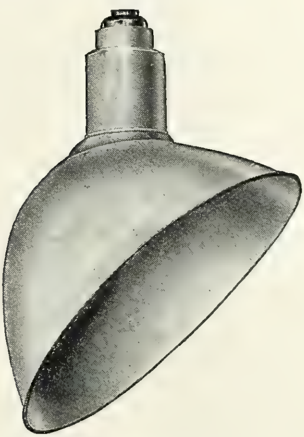

Fig. 8.—Large size angle reflector, porcelain enameled steel. (Photometric curve shown in Fig. 9.)

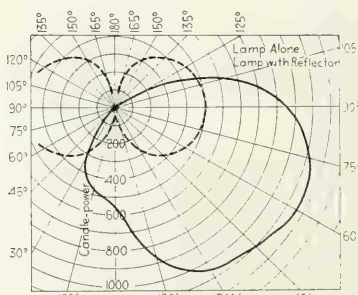

Fig. 9.—Photometric curve of large size porcelain enameled angle steel reflector with 500-watt clear tungsten lamp operating at 1.00 watt per candle. (Reflector shown in Fig. 8.)

Irregular reflection of the individual light-rays (Fig. 2-b) causes a spreading of the light, resulting in spread reflection. This is produced by any matte surface. The surface of this character most widely used for reflectors is the applied aluminum finish. Diffuse reflection is almost invariably produced by reflection of light-rays from particles beneath the surface (Fig. 2-c). The most widely used surface of this character is porcelain enamel. Porcelain enamel is, in reality, a glass having the characteristics of opal. The minute particles held in suspension in the glass are the reflecting media. In addition to the light reflected from these particles beneath the surface, there is a small amount of reflection from the surface itself. This reflection is regular since the surface is smooth. The result is a combination of diffuse and specular reflection as shown in Fig. 3. The light reflected specularly is usually negligible in quantity, but cannot be entirely overlooked, especially in reflector design.

Surfaces giving specular reflection afford a high degree of light control and polished metal reflectors could be designed to give almost any desired distribution of light. Such surfaces are very little used, however, due to the streaked character of the illumination obtained from them. The polished aluminum reflector, used considerably several years ago, is now well-recognized as a highly undesirable reflector because of the striations or streaks in the resulting illumination. Surfaces giving spread reflection are only slightly less susceptible to accurate design than surfaces giving specular reflection since with spread reflection, the major portion of the reflected light deviates only slightly from the law that the angle of reflection is equal to the angle of incidence. Aluminum finished reflectors, for example, can be accurately designed to give all the most widely useful kinds of light-distribution. Diffusely reflecting media, however, such as porcelain enamel and paint enamel, have a much narrower field of usefulness. Extreme distributions of light, such as the focusing type, cannot be obtained with reflectors of this character. The law of diffuse reflection is a law which can be accurately applied to reflector design, but the possibilities of obtaining varied distributions of light with diffuse reflectors are exceedingly

limited. The users of reflectors and even the manufacturers in many cases, have quite generally failed to recognize this.

Referring again to the classification of metal reflectors, it will be seen that in shape there are four general classes—deep bowl, shallow bowl, shallow and angle. Deep bowl, shallow and angle types of reflectors are well known. The shallow bowl has been less generally used. Figs 4, 6, 8 and 10 show typical reflectors of these four classes. The deep bowl and the angle types (when the latter are rightly used) are much preferable to the others from the standpoint of protecting the eyes from exposure to brilliant lamp-filaments. The shallow bowl and shallow reflectors, however, are the only shapes giving a distributing type of curve and this curve has certain fields of usefulness. As a subclassification of shallow reflectors, the flat type might be mentioned, although these are rapidly becoming obsolete. Flat reflectors usually allow the lamp filament to protrude too far below the lower edge of the reflector. The shallow reflectors now most commonly in use are sufficiently deep to cover the lamp at least to the bottom of the filament.

Distribution of light is perhaps the most useful method by which reflectors can be classified. Certainly, in selecting the reflectors for use in any installation nothing is more important than to obtain the best distribution of light for the purpose. Extensive, intensive and focusing distributions are well-known and widely used. The prototype curves of these distributions (*i e.*, the original curves which reflectors should be designed to give) are calculated on the basis of obtaining uniform illumination when the light-units are arranged in squares with the distance apart bearing a definite ratio to the height above the plane of illumination. These ratios of distance apart to height are 2 for the extensive distribution 1¼ for the intensive distribution and ¾ for the focusing distribution. Fig. 4 shows an illustration of the well-known extensive reflector and Fig. 5 shows its photometric curve; Figs. 12 and 13 show the illustration and curve of an intensive reflector and Figs. 14 and 15, a focusing reflector. Reflectors most nearly approaching the prototype curves have been selected. Reflectors giving these distributions are available for inverted gas and for nearly all the various sizes of tungsten

lamps. Extensive and intensive reflectors are available in both aluminum and porcelain enamel finish, although reflectors having porcelain enamel finish cannot be designed to give as good an extensive distribution as reflectors having an aluminum finish. Focusing reflectors are not available in porcelain enamel since, as stated above, a focusing distribution cannot be obtained with a diffusely reflecting surface.

The distributing type of photometric curve is characterized by high candle-power values at the angles of 50° to 75° from the nadir or vertically downward direction. To obtain high candle-power values at these angles it is necessary to expose the lamp filament considerably more than in the case of reflectors giving extensive, intensive and focusing distributions. Consequently, while deep bowl reflectors may be used to obtain extensive, intensive and focusing curves, shallow or shallow bowl reflectors must be used when a distributing curve is desired. Figs. 7 and 11 show good distributing curves obtained from a shallow porcelain enameled reflector and a shallow bowl aluminized reflector respectively. This radical difference in shape of reflector to obtain the same type of distribution is due to the radical difference in the character of the reflection obtained from porcelain enamel and aluminum, as explained above. Shallow reflectors if made with an aluminum finish would not give a distributing curve unless the lamp filament were allowed to project considerably below the edge of the reflector, thus wasting entirely too much light at and above the horizontal. Fig. 16 illustrates this, by showing the photometric curve of a shallow type of reflector in porcelain enamel and the curve of the same reflector in aluminum finish. It will be seen that the change in finish has changed the character of distribution entirely. The aluminum finished shallow reflector has little practical value. It is not distributing, while as a focusing type it has too high candle-power values at 50° to 75° from the vertical, and does not protect the eyes from the lamp filament to as great a degree as the regular types of focusing reflectors. When a distributing curve is desired in aluminum finish the shallow bowl type of reflector should be used. This shape was developed solely to obtain a distributing reflector in aluminum finish.

Distributing reflectors have been more generally used than they should have been. As stated above, their principal characteristic is high candle-power values at angles of 50° to 75° from the nadir. To obtain these high candle-power values a certain degree of eye-protection is sacrificed. Consequently they should be used only where the light at these high angles is of more importance than the better eye-protection which would be obtained with deep bowl reflectors. There are certain cases where light at high angles is of importance. For example, when illumination is required on many different vertical or oblique surfaces, high above the floor, the distributing reflector will often prove the best reflector to be used. It frequently happens, however, that such cases are better taken care of by the proper type of angle reflector. As another example, large stock-rooms and warehouses should usually be lighted with distributing reflectors. Here little actual work is performed and exposure of the lamp filament is permissible, while to obtain a reasonably low cost of installation, the light-units must be placed far apart. When the distance apart is greater than two and one-half times the mounting height, extensive reflectors will leave dark spots half-way between light-units. Distributing reflectors will eliminate these dark spots. It must not be supposed, however, that distributing reflectors will give uniform illumination at wide spacings. Their advantage lies simply in the fact that at these wide spacings, they do not allow the intensity of illumination half-way between units to drop as low as other reflectors do. To obtain uniform illumination, extensive reflectors can be used farther apart than any other type of metal reflectors on the market. The spacing constant for uniform illumination with extensive reflectors is $k = 2$, *i. e.,* distance apart should be two times the height above the plane of illumination. The distributing curve does not give uniform illumination unless the spacing is $k = 1.6$ or less, thus requiring units considerably closer together than when the extensive distribution is used. This does not mean that distributing reflectors should be installed at the spacing $k = 1.6$ or distance apart 1.6 times the mounting height. When uniform illumination is desired extensive, intensive or focusing reflectors should be used.

Fig. 10.—Shallow bowl type of distributing reflector, aluminum finish. (Photometric curve shown in Fig. 11.)

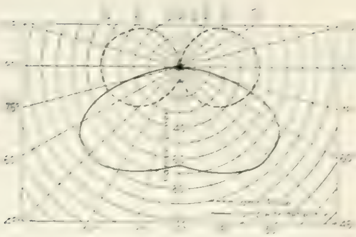

Fig. 11.—Photometric curve of shallow bowl type distributing reflector, aluminum finish, with 60-watt clear tungsten lamp operating at 1.16 watts per candle. (Reflector shown in Fig. 10.)

Fig. 12.—Intensive aluminum finished steel reflector. (Curve shown in Fig. 13.)

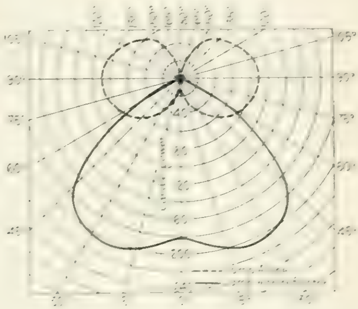

Fig. 13.—Photometric curve of intensive aluminum finished steel reflector with 100-watt clear tungsten lamp operating at 1.15 watts per candle. (Reflector shown in Fig. 12.)

Fig. 14.—Focusing aluminum finished steel reflector. (Photometric curve shown in Fig. 15.)

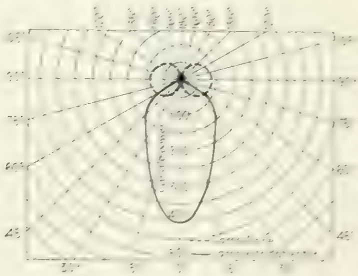

Fig. 15.—Photometric curve of focusing aluminum finished steel reflector with 100-watt clear tungsten lamp operating at 1.13 watts per candle.

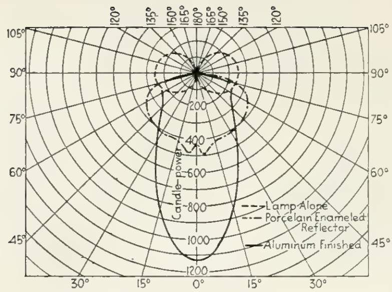

Fig. 16.—Photometric curves of shallow dome type reflector, porcelain enamel and aluminum finished with 250-watt clear tungsten lamp operating at 1.00 watt per candle.

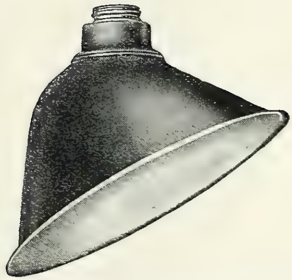

Fig. 17.—Small angle type of reflector, aluminum finished. (Photometric curve shown in Fig. 18.)

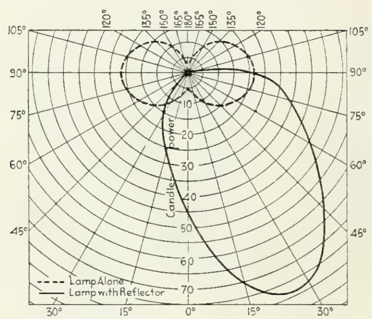

Fig. 18.—Photometric curve of small aluminum finished angle steel reflector with 25-watt clear tungsten lamp operating at 1.18 watts per candle.

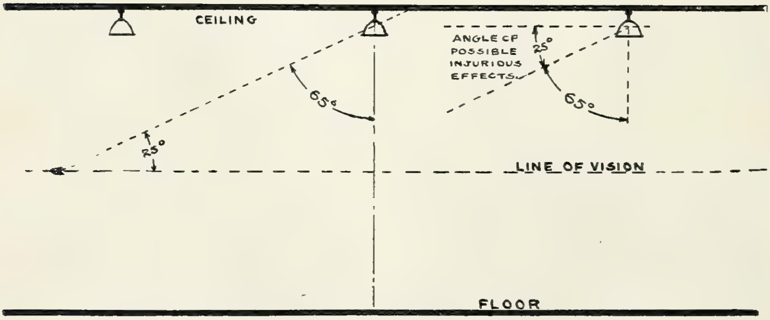

Fig. 19.—Diagram showing angle above which light emitted from light-units is likely to cause eye-strain.

Distributing reflectors are for wide spacings where uniform illumination is unnecessary.

The fact that distributing reflectors are less undesirable than extensive with very wide spacing of light-units causes their use in many cases where closer spacing and extensive or intensive reflectors would be preferable. Often a false idea of economy dictates too small a number of outlets and distributing reflectors are the only recourse. The result is non-uniformity of illumination and lack of diffusion. Shadows are too dense and light comes from the wrong direction for many of the workers. The competition among reflector salesmen is frequently responsible for this. It is naturally easiest to sell the reflector which can be used at the widest spacings since the installation cost is then the lowest. Again, the old fallacy that light is more important than illumination is responsible for the use of many shallow reflectors. In spite of the great spread of illumination knowledge in the last few years, there is still a general impression that lamp filaments must be in plain sight to obtain the best results. This tends to increase the sale of shallow reflectors at the expense of the more desirable deep bowls. A still more widespread knowledge of the principles of good illumination will gradually remedy this condition. Industrial lighting is still passing through the stage which the general commercial field passed some years ago. Shallow types of prismatic reflectors are practically obsolete; shallow opal reflectors are rapidly becoming so, but shallow metal reflectors are still used in large quantities. It is true that with an opaque reflector and in a field of such diversified requirements as the industrial field, there is some need for a shallow reflector, but it must be admitted that the use of this type is much more general than it should be.

The last class of reflectors given in the table under the classification "Distribution of Light" is the asymmetric class. Asymmetric distributions are obtained from angle reflectors. These reflectors are usually made up of symmetrical reflector forms with the holders set at an angle. They are available in aluminum or enamel finish for all sizes of tungsten lamps from 25-watt or smaller to 500-watt. The small sizes are used principally for local lighting such as the lighting of benches or particular por-

tions of the work on machines. They are made to give various distributions. They can be obtained in the sizes up to 8 inches (20.32 cm.) in diameter of such shape that the maximum candle-power is given in any direction desired from directly downward to directly horizontal. Most conditions, however, can be met by a single line of reflectors, *i. e.*, one angle type only for each size lamp. For the small sizes, used principally for local lighting, the greatest candle-power values should be between 15° and 45° from the vertical. For the larger sizes, the greatest candle-power values should be between 35° and 80° from the vertical. It should be noted that the angle at which the holder is set does not indicate the direction in which the maximum candle-power is obtained. It is characteristic of these reflectors that they give the greatest candle-power and greatest flux of light at angles somewhat higher than the angle at which the holder is set. Fig. 17 illustrates a typical small angle reflector and Fig. 18 its photometric curve. A typical large angle reflector is shown in Fig. 8 and its photometric curve in Fig. 9. Such reflectors are not used for local lighting to as great an extent as the small reflectors. They are of value for general illumination, when there are vertical or oblique surfaces to be lighted at a considerable height above the floor. They are also widely used for the general illumination of spaces in which it is difficult to place symmetrical reflectors effectively. Many shops, for example, have traveling cranes which either interfere with the placing of reflectors above them or require such reflectors to be placed so high as to lose much of their effectiveness. In such cases the large angle reflectors, placed on the upright girders beneath the crane, may be used to advantage.

The above treatment of reflectors according to their various characteristics does not include several important features which must be considered in selecting a reflector for any given service. In the classification which has been made, eye-protection has been considered only slightly, in connection with the shape of the reflector. Efficiency, depreciation and cost have not been considered. The classification gives a broad general idea of the characteristics of metal reflectors; but for an intelligent selection of reflectors for any given installation the following points should

be considered: (1) eye-protection; (2) distribution of light; (3) efficiency; (4) depreciation; (5) cost.

The above order in which these points are given will, in many cases, be the order of their relative importance, but this will vary somewhat, depending upon the character of the building. These five considerations will be treated briefly from the standpoint of their influence on choice of reflector.

The proper protection of the eyes, as far as is known at present, involves the avoidance of three undesirable features, namely, high candle-power, points of high intrinsic brilliancy and extreme contrasts of brilliancy within the ordinary range of vision. When work is actually being performed the worker is usually looking in a downward direction. Wherever this is the case, only the most flagrant violation of the principles of good lighting (such as placing a bare lamp in front of the worker and close to the work) will cause serious eye-strain. However, when the worker glances up from his work, if he encounters conditions causing eye-strain, the eyes are temporarily rendered less efficient and it may be some minutes after he looks down again, before his vision is normal. It is desirable, therefore, in factory lighting to minimize the possibility of eye-strain for all ordinary conditions of vision. The first requirement for this is to place light-units as high above the range of ordinary vision as is consistent with good distribution and diffusion of illumination. In large rooms, distant light-units, even if placed high, will nearly always be in the range of vision and it is important that the units themselves be so designed as to avoid insofar as possible, the conditions which lead to eye-strain. Research has shown that high candle-power ceases to affect the efficiency of the eye, when it is removed to 25° from the direct line of vision. It is reasonable to suppose that high intrinsic brilliancy and strong brilliancy contrasts also have little effect when the light-source is so far removed from the line of vision. Assuming that the direct line of vision will not often be above the horizontal, the requirements of light-units to obtain best eye-protection are that the candle-power, intrinsic brilliancy and brilliancy contrast be low at angles above 25° below the horizontal or 65° from the vertical. This requirement is lenient since in many shops the eye is quite frequently directed

above the horizontal. However, the injurious effect of light within this angle of 25° varies with the angle. The greater the angular distance of the light from the line of vision the less will be the injurious effect. The effect, therefore, becomes quite small when the angle is only slightly less 25° from the line of vision.

The suppression of candle-power above 65° from the vertical is satisfactorily accomplished in the deep bowl reflectors of the extensive, intensive and focusing types. The suppression of intrinsic brilliancy at these angles requires the screening of the filament down to 65° from the vertical. Most deep bowl reflectors do not meet this requirement exactly; the screening angle varies from 65° to 75°. Nevertheless, deep bowl reflectors are reasonably satisfactory in this respect and are, of course, much preferable to the shallow bowl reflectors. The avoidance of strong brilliancy contrasts above 65° from the vertical, is not always easily accomplished. When deep bowl reflectors are used, there is often a considerable degree of contrast between the brilliant interior of the reflector and the dark upper portion of the room. Where these reflectors are used in rooms having light colored ceilings and the work is principally on light colored goods, this strong contrast is not so much in evidence. In many cases, however, there is practically no ceiling and frequently what ceiling there is, is dark in color. In order to relieve this contrast, it is important that the interior of the reflector have as low a brilliancy as possible in the directions above 65° from the vertical. If the character of the reflection obtained from an aluminum surface and from a porcelain surface is carefully considered, it will be seen that this has considerable effect upon the appearance of the interior of the reflector. Aluminum reflectors act by spread reflection. In other words the maximum candle-power of the reflected light is at the same angle with the surface as the incident light. In the design of these reflectors, their contour is made of such a shape that this feature is utilized in directing the light into the directions where maximum candle-power is desired. In the extensive, intensive and focusing distributions, maximum candle-power is desired below 55° from the vertical. Consequently, the interior of the aluminum finished

reflector appears brightest when viewed from below 55° from the vertical. Both the candle-power and the intrinsic brilliancy of the interior surface are comparatively low at 65° and above. With the porcelain enameled reflector, conditions are somewhat different. The reflection is diffuse and the maximum candle-power from every point on the surface is in a direction normal to the surface. With diffuse reflection much of the light at each reflection is directed back into the reflector and strikes the surface again. The consequence is that the entire interior surface of the reflector has approximately the same degree of brightness. In looking at such a reflector at angles above 65° from the vertical, one sees an interior surface of the same brightness as would be seen from directly underneath. The candle-power is low at these high angles because the edge of the reflector cuts off the light from a large part of the opposite side of the reflector. The intrinsic brilliancy, however, and the degree of brilliancy contrast are considerably higher than with an aluminum finish reflector of the same shape.

These considerations indicate that from the standpoint of eye-protection, the most desirable reflector is the deep bowl in aluminum finish; second choice is the deep bowl in porcelain enamel finish, while least desirable from this standpoint are the shallow bowl and shallow types of reflector.

The question of distribution of light has been covered above in a general way. It is not necessary here to describe in detail the characteristics of the extensive, intensive, focusing and distributing photometric curves. These distributions are well known and their relative merits and uses have been treated before. It is important that reflectors should be selected for a given service by their distribution of light. There is too great a tendency at present to consider shape of reflector as important in selection. Having settled the question of eye-protection in any given installation, shape should be entirely disregarded and distribution considered. For example, the distributing type of photometric curve is obtained from two reflectors of entirely different shape, one in aluminium finish and one in enamel finish. The shape of these two reflectors should be neglected in choosing between them and the choice made on the basis of their other characteristics.

In comparing reflectors on the basis of efficiency, it is important to consider efficiency in the sense of illumination obtained for energy expended. The total output of a reflector is no measure of its illumination efficiency. If this were the case, a bare lamp would be more efficient that a lamp and reflector. It is obvious that a shallow reflector will have a greater total output of light than a corresponding deep reflector, since with the shallow reflector much less of the light from the lamp strikes the reflector and there is, consequently, less absorption at the reflecting surface. This greater total output with shallow reflectors does not mean that a higher percentage of the flux of the lamp will be useful. Only in exceptional cases is this greater total output a distinct advantage. In comparing the efficiency of reflectors in any given installation, an illumination test is the most satisfactory method. Certain comparisons from the photometric curve, however, may be made to advantage when an illumination test is impractical. The light-flux in the zone 0° to 60°, or below 60° from the vertical, is used considerably in comparing the effective flux of reflectors. This zone includes on the average, the light striking the plane of illumination directly, in large rooms. In medium-sized rooms, the angle including the directly effective flux is somewhat lower. Flux in the zone 0° — 60° is a much better basis of comparison of the efficiency of reflectors, than total output or flux below the horizontal.

The specific reflecting efficiencies of aluminum finish and porcelain enamel finish are very nearly the same. Porcelain enamel will usually run somewhat higher. The actual efficiency obtained from any given reflector, however, depends much upon the shape of the reflector. With shallow reflectors, porcelain enamel is considerably more efficient than aluminum. With the deep types, however, the diffuse character of the reflection from porcelain enamel tends to cause much of the light to be reflected back and forth within the reflector. This increases the amount of light absorbed, and, as a consequence, in the deep bowl reflectors, aluminum finish is more efficient than porcelain enamel.

The deterioration of reflectors, due to the collection of dust, is an important consideration in industrial lighting. Dust and dirt are much more prevalent than in the general lighting field

and consequently more apt to reduce the efficiency of the lighting system. Among metal reflectors the principal difference in this respect is due to difference in finish. Reflectors with a smooth interior surface such as porcelain enamel are naturally more easily cleaned than those with a rough surface such as the usual types of matte aluminum. Furthermore, porcelain enamel reflectors after cleaning regain their initial reflecting efficiency, while the usual types of aluminum finish, after once becoming dirty, can never be cleaned sufficiently to regain their original condition. They always show a permanent deterioration in reflecting efficiency of 5 per cent. or more, the exact percentage depending upon the character of the dirt. It is unfortunate that this is the case in view of the other advantages possessed by aluminum finished reflectors. The search for a method of overcoming this permanent deterioration and difficulty of cleaning has not been entirely without success. A finish has recently been developed which will undoubtedly do much to increase the popularity of aluminum. This consists of an interior finish comprising three distinct coats of different material instead of the one coat of aluminum usually employed. The lower ground coat consists of a white material which is practically impervious to moisture. This serves the double purpose of protecting the reflector from rust and slightly increases the efficiency since some light usually penetrates the aluminum finish in places. The second coat is the ordinary aluminum finish. The third consists of a washable lacquer. This forms a smooth hard surface which is easily cleaned, and when cleaned, restores the surface to its initial efficiency. This coat is, of course, transparent and the absorption is so low that the decrease in efficiency due to its use is much less than the permanent deterioration of the ordinary aluminum finish after its first cleaning. In addition to the three inside coats, the outside of the reflector is finished with the same ground coat as the inner surface, after which the usual paint enamel is applied. The reflector, therefore, has 5 coats instead of the 2 ordinarily used. This finish bids fair to overcome the last objection to the use of aluminum finished reflectors. Aluminum finish will undoubtedly become more popular than ever before and gradually replace the less desirable porcelain enamel.

The comparative cost of various reflectors is a subject which must be considered for the individual case rather than in any general treatment of the subject. Reflectors vary in cost due to differences in finish more than due to differences in shape. Of the finishes in common use, the aluminum is somewhat lower in cost than porcelain enamel. Initial cost is worthy of very little attention, however. The value of obtaining the best illumination results far outweighs such considerations as cost of reflector and cost of installation. Take for example, the lighting of a single machine. The best reflector for the purpose may cost 80 cents. The machine is worth several hundred or very likely, several thousand dollars. Considering the reflector as a necessary part of the equipment of the machine it is apparent that its cost is insignificant. Again, consider the value of the workman's time; 25 cents an hour is a low price, but even at that figure the loss of only a few hours due to poor eye-protection or poor illumination, would offset the entire cost of the best reflector obtainable. Or, take the value of the work performed. An hour's work of a single workman may be actually worth several dollars to the company. Yet one mistake due to poor eye-protection or poor illumination may require many hours' work to rectify it. These comparisons are sufficient to show that reflectors should not be selected by cost but rather by the results which they produce. Illuminating engineering has advanced to such a position that the best lighting system which a factory can install is usually worth many times what it actually costs.

From the above treatment of the factors influencing the choice of reflector, the following generalizations may be made.

1. Aluminum finished reflectors are preferable to porcelain enamel from the standpoints of
   a. Variety of distribution obtainable.
   b. Protection of the eyes.
   c. Low cost.
2. Porcelain enamel reflectors are preferable to aluminum from the standpoint of ease of maintenance and lack of permanent deterioration except when the aluminum finish is protected by a smooth transparent lacquer; in that case

the two finishes are probably equally good, for most classes of service.

3. Deep bowl reflectors are preferable to shallow bowl and shallow reflectors from the standpoint of,
    a. Protection of the eyes.
    b. Variety and usefulness of distributions available. (Deep bowl reflectors are available giving extensive, intensive and focusing distributions. The shallower reflectors give only a distributing type of curve.)
4. Extensive, intensive and focusing photometric curves are preferable to the distributing curve for the majority of cases of general lighting. The distributing curve should be reserved for special cases such as warehouses, stockrooms, etc., or work-rooms in which light is required on high vertical surfaces.
5. Initial cost of reflectors is of minor importance. It should usually be disregarded, except in comparing reflectors which are equally good in other respects.

DISCUSSION.

Mr. H. Calvert: It is certainly true that in the industrial field there are many crimes committed against the conservation of vision,—bare lamps suspended in the line of vision, improper reflectors, and lamps badly located. Comparing industrial lighting with the lighting of stores, the difference shows up very much to the disadvantage of the factories and workshops, and I think the reason is not very hard to find. The storekeeper naturally wants to attract the public into his store and to do this he is generally willing to spend a certain amount to improve his illumination, thinking in doing so that it will increase his profits. The factory manager, on the other hand, does not come in contact with the public; the public does not enter his factories, and he is very apt to consider that any money spent on such illumination means a decrease in his profits.

There is no question that great improvements can be made by the reasonable use of metallic reflectors. I have in mind a

large weave room which was originally illuminated by means of 86 series arc lamps with clear globes. These were replaced by 171 100-watt tungsten lamps with shallow bowl reflectors. The result was a great improvement in the lighting, greater uniformity, and a decrease of approximately 40 per cent. in the energy consumed.

This installation brings to mind an interesting psychological study. The same mill had a similar weave room which was lighted practically the same way—the same illumination, but in the first room of which I spoke the lamps are practically exposed. In the second room a deeper shade is used, so that the lamps are entirely hidden from view. Now the operators in the second room are firmly of the opinion that they do not get as much light as the operators in the first room, simply because they cannot see the sources of light.

Mr. C. O. Bond: I would wish only to call attention to one installation of deep bowl metal reflectors, which I think would appeal to anyone seeing it, that is along the line of the underground platform at the West Philadelphia station of the Pennsylvania Railroad Company. As one goes down to take the train to Baltimore, or going South, there is quite a long platform. In going up or down such platforms one receives a glare of light in the eye; and the approaching engineer is so blinded as he comes down the track that he almost finds himself in the position of being unable to tell whether he is running into danger or not. The use of deep bowl reflectors has solved the problem in this particular case very well indeed and I think it is worth while for anyone to study that installation.

I should like to ask Mr. Rolph if the local reflection in the deep bowl reflectors has any influence whatever on the length of original life of the filament. I was wondering whether there is a similar effect found by frosting the bulbs of electric lamps, in which I think the shorter life is somewhat due to the increased temperature. I ask for that information.

Prof. George A. Hoadley: Mr. Calvert has called attention to the fact that in many factories there are high ceilings, and I am

pretty sure that anyone present can appreciate the difficulties in lighting such places.

Mr. Rolph has spoken of the metal reflectors, and it occurred to me that in their use we get the type of lamp known as the direct type. Now is there any particular portion of the light that comes from these reflectors that is reflected on the walls, thus giving a bad effect in the illumination of the room? I have thought of that as one of the things which might be taken up.

Another point is, that it seems to me it would add very much to our information if we could have two illustrations—one showing the ordinary daylight, and the other which would give what we might term artistic illumination. Then we would be able to make a contrast between the two. But if we have only one, or only daylight, while we get sufficient information in connection with the lamp, it does not seem to me that it gives all the information we ought to get.

Prof. Arthur J. Rowland: Some one ought to write the history of shades. I presume that on sources of light being open flames they were originally used for either of two purposes: to cut light off from a particular direction where it was not desired, or to serve to reduce the risk of setting fire to objects in the vicinity. I incline to the opinion that most shades used on electric lamps, prior to the day of tungsten lamps, were there because their use was in accord with common practicable gas burners; not to produce any special redistribution of light, or to soften the brightness of a small area light source. Then again one feels that a bare light is uncouth and crude.

When it comes to shades planned to redistribute light, it is easy to think there are great differences where none exist. Take a simple, opaque, cone shade with a white diffusing surface; the redistribution produced is practically independent of the angle of the cone or the way it is placed with reference to the lamp; except that more or less light is entirely cut off as the light is pushed further into the cone or partly withdrawn. I am wondering how much these more modern opaque shades differ from the simpler and older forms in the light distribution they are able to produce.

In Mr. Rolph's paper the word efficiency has been used quite a little, but nothing has been said about how much the efficiency is; that is what per cent. of the total light the bare lamp would pour out, is still poured out from the lamp with any of these shades over it. It seems curious to me how little manufacturers care to give that information. Efficiency ought to be as important as candle-power distribution, for this last has great importance only where a relatively small number of sources is in use.

I wonder whether some of the first intelligent efforts to produce efficient shades for ordinary lights giving a desirable light distribution were not made right here in Philadelphia. Prior to the time when the names Holophane-D'Olier were coupled as describing a certain line of opaque shades, a large part of the line was made by the D'Oliers here in our town. At the beginning of that work, if my recollection serves me correctly Prof. Edwin Houston, so well known in Philadelphia, made the designs for the shades, the metal used being aluminum. Shortly after this time the factory superintendent struck trouble. The aluminum shade with its polished reflecting surface reflected the light all right but the "streaky" illumination was produced. Something had to be done. The superintendent had to devise some remedy. In his difficulty he came out, for some reason or other, to see me at Drexel Institute. He stated the case and asked me to suggest some process by the use of which the inside of those aluminum shades could be given some sort of a matt surface. I had to tell him I was unable to help, since the question was a chemical one. I took him to Prof. Henwood, head of the department of chemistry who said at once, "Wash them with a little caustic soda." "Oh," said my friend, "Will anything as simple as that really do it?" "Yes," said Prof. Henwood, "Nothing more is necessary—try it." After that they made their whole product that way.

I had hoped that this evening the discussion would leave the subject of shades and consider the broader subject of industrial lighting. There is one very important great detail of industrial lighting which seems to have been given but little attention by anyone; that is, the accumulation of data which will give the an-

swer to this question, "Is it or is it not worth while to light rooms and machinery correctly and well?"

About a week ago I learned from a man who has made an investigation to determine the effect of artificial lighting on output and on the operator. That nervous strain as indicated by the presence of nervous headaches, could be eliminated, in the case of girls working in the printing industries, by using appropriately shaded lamps and requiring the operators to wear eyeshades. He added that the time required on adjusting, making repairs to machinery, etc., could be very considerably diminished by a permanent installation of lights at the places where adjustments and repairs were made. The results he said were almost too good to believe, and that he would not tell anyone how good they were because he feared the facts might be discredited. He had not reached the point of considering quality of output, or safety of employees, when the investigation was discontinued. Surely some day some one will conduct an elaborate investigation taking up and determining not only the effect on the output, as to both quality and quantity, when good artificial lighting is provided and whether its expense is warranted; but also how a worker stands his day's work and how much increased safety is secured to him by the use of good lighting.

Such questions are as important as any which can be considered in connection with industrial lighting. The kind of lights used, their arrangement, the kind of shades put on them, are insignificant matters compared with the money value of good light to the industries. This will have to be determined somehow if industrial lighting is to come into its own.

Mr. J. W. Lee: I should like to ask Mr. Rolph's opinion regarding glass reflectors and metal reflectors for industrial lighting. It appears to me that in large rooms, where the ceilings and the walls are white, and the lamps are hung high, that glass reflectors have a particularly pleasing effect—the cheerful aspect of the light ceilings and light walls have such an effect, to my mind. Is there any real objection to a glass reflector—which is more efficient than either the aluminum or metal reflectors—being used for industrial lighting?

Mr. T. W. Rolph (In reply): In regard to the point that Mr. Bond brought out on the effect of multiple reflections—I do not believe that I have any more information that he has on that point, with the possible exception of the heating effect. Of course this multiple reflection is a reflection of heat as well as light, and I can say that the heating effect has no effect upon the life of the lamps. Careful temperature tests which have been made show that the temperature obtained in all types of deep bowl reflectors—aluminum or porcelain enamel—is not sufficient to affect the life at all. It is reasonable to suppose that the decrease in the effective light of the lamps would be greater for porcelain enamel deep bowl reflectors, on account of the multiple reflection back through the bulb; and when the bulb begins to blacken the absorption will increase. As Mr. Bond pointed out, it is exactly the same as with frosted lamps. With frosted lamps the actual life of the lamp is just as great as with the clear lamps, but the effective light, to 80 per cent. of candle-power is only about half as great—simply due to the cross-reflection in the bulb.

Professor Hoadley brought out the point of the reflection from walls with metal reflectors. Of course with small installations there is considerable reflection from the walls and the actual diffusion of course is bad. Diffusion is obtained by light from distant units in large installations. With metal reflectors there is not as great diffusion, as a general rule, as with glass reflectors, but in industrial lighting usually metal reflectors can be so placed that the direction of the light will be satisfactory for direct light, so that great diffusion is not necessary.

The question of glass versus steel is one that ought to be discussed at considerable length if discussed at all. I will barely touch on it, on the point of efficiency. The most efficient types of glass reflectors are more efficient than steel when the ceilings are very light in color. When ceilings are dark in color the efficient types of steel reflectors give a higher efficiency than most types of glass reflectors. There is a question of depreciation to be considered. Of course when bare lamps and glass reflectors are used to give a higher efficiency in illumination,

the efficiency which they give is obtained by reflection from the ceiling to a certain extent, and naturally the depreciation would be a little greater than with steel reflectors. There are undoubtedly many cases where glass reflectors are better than steel reflectors in industrial lighting. But in the great majority of cases it seems that steel would be more satisfactory. Glass reflectors are appropriate in rooms where the conditions of dirt are not bad, and in general, in light-colored rooms, where the work is clean, glass reflectors are quite satisfactory. As I say, however, that is too big a question to discuss here in detail. I did not quite get Professor Rowland's point, on the diffused reflection—on the character of distribution you get with a reflector when the reflector is used more as a shade.

PROF. A. J. ROWLAND: No matter what the angle of the reflector, or what its size, the redistribution of light is essentially the same.

MR. T. W. ROLPH: Yes, that is true, with diffusing reflectors; the general distribution of light from a diffuse reflector is very nearly the same, no matter what the shape. The shape of the reflector has some bearing on efficiency--not very much on the distribution of light—and the extensive curves obtained with porcelain enamel reflectors are not as good—not as wide, truly typical extensive curves—as those obtained with aluminum reflectors.

Professor Rowland asked about the efficiency of reflectors. Deep bowl aluminum reflectors give a total output of 55 per cent. to 65 per cent. of the total flux of the lamp. Deep bowl enamel will run from 50 per cent. to 65 per cent. Some of the deep bowl in enamel finish will run just as high as in aluminum finish, but those are reflectors in which the widest part does not come down quite as far as the corresponding aluminum reflector. The deep bowl reflectors, which come down well over the filament protecting the eyes well, are a little bit under the aluminum finish in efficiency. In the shallow type of reflector less light strikes the reflector and consequently shallow reflectors will vary from 70 per cent. to 85 per cent. depending for the efficiency of reflection upon the character of the material used.

There is a great deal to be learned, as Prof. Rowland pointed out, in regard to the effect of good illumination upon the efficiency of the work in industrial lighting. There are many investigations which ought to be made very much along the same lines as the investigations which have been made on motion study and investigations along such lines as that will show the efficiency of the workers under various systems of illumination. I have no doubt when we get data of that character it is simply going to be astounding, in showing the increase in output and decrease in accidents, and such effects of good illumination. Undoubtedly such investigations will be made in the near future— a great many of them—because it is too big a commercial question to leave alone very long.

Mr. W. F. Little (Communicated): Mr. Rolph has given very clearly his views on the ideal reflector for industrial lighting and has put on record his opinions as to the best material and shape as well as on the proper methods of installations.

He refers also to the very noteworthy development of a more durable aluminum finished reflector. In the past it has not been exceptional nor even unusual to find a reflector of this type which has shown a depreciation in reflecting power of 15 to 20 per cent. in a short time, even though it had received more than ordinary care. Once the lustre is gone, an aluminum finished reflector of the ordinary type has permanently lost much of its efficiency. If the white protective lacquer referred to by Mr. Rolph reduces the efficiency but 5 per cent., and prevents further depreciation, its use marks an important improvement.

Mr. Rolph will probably find many who feel that the flat or shallow type of porcelain enamel reflector is not such a back number. In a great deal of industrial lighting where opaque reflectors are suitable, the conditions are such as to require general illumination at an angle greater than 65 degrees from the vertical. Furthermore, by using a distributing reflector of somewhat higher efficiency, throwing some illumination nearer the horizontal, the contrast between the reflector and background may perhaps be lessened without a substantial loss in the illumination on the working plane, thus producing effects more agree-

able and equally free from eye strain. Possibly in a majority of cases this illumination near the horizontal will not be wasted.

It is further implied by Mr. Rolph that for most installations the bowl type aluminum reflector is preferable to the porcelain enamel on account of the fact that aluminum produces an "irregular reflection" while enamel produces a "diffuse reflection." Also that the light between 65 degrees and horizontal decreases the ability to see, and that the strain increases with the angle. Further, that the specific intensity of the reflecting surface will be greater in the enamel bowl type reflector than in the aluminum reflector of the same type because of the reasons indicated.

In comparing the two types of reflector it should be noted, first, that the degree of diffuse reflection secured from porcelain enamel is largely dependent on the quality of the enamel surface. It is quite possible to secure enameled reflectors which will control light almost as accurately as aluminum reflectors. Enamel of this quality will of course be of a higher order of efficiency. Second, while it is true that the light between 65 degrees and the horizontal decreases somewhat, the ability to see, nevertheless experiments have indicated that the amount of the decrease has been greatly overestimated and that it is not nearly as important as some observers have maintained.

Mr. T. W. Rolph (Communicated): Mr. Little's statement in regard to enameled surfaces which do not give a high degree of diffuse reflection is very interesting. If such surfaces can be used for reflectors and can control the light as accurately as aluminum finished reflectors, they have a wide field of usefulness. A reflecting surface, for use on metal reflectors, which will control light accurately and which can be as easily cleaned as porcelain enamel and which does not give the disagreeable streaked effect of polished metal, will be a very valuable addition to the materials in use at present.

VISION AS INFLUENCED BY THE BRIGHTNESS OF SURROUNDINGS.*

BY PERCY W. COBB.

The often-repeated remark that the number of foot-candles upon the work is not an adequate indication of the virtues of an illumination system, even solely with respect to that particular work; the recounting of experience in corroboration of this fact, and the experimental attempts that are being made to ascertain the reason, and give quantitative expression to it, are conditions which make a very limited amount of introductory matter adequate to the present paper.

This paper constitutes an attempt to answer the question: "How is vision influenced by the bright, visible surroundings of its particular object?" The experimental method by which the work here outlined was done is briefly thus: An observer sitting in a dark room faces a bright surface of small dimensions transilluminated from the next room. At a given moment the bright spot thus seen is replaced for a short time by a field of black and white lines of the same outside dimensions and the same average brightness. By repeating the experiment with lines of various widths the exact width of the lines can be determined which is necessary in order that they may be just visible.

Similarly, instead of using a lined surface, the original blank surface can be replaced by a field of the same brightness, except that one half of it is increased or diminished by a small fraction of its intensity. In this way can be determined the exact difference necessary in order that it may be seen as a difference. As both of these quantities (smallest visible detail and smallest visible difference) vary with variations in brightness, the determination was made for a series of seven different brightnesses, from a mere glimmer up to the highest capacity of the apparatus.

These experiments were then repeated with the observer's eye,

* A paper read at the sixth annual convention of the Illuminating Engineering Society, Niagara Falls, Ont., September 16-19, 1912.

instead of being in the darkness, exposed to white surface illuminated as nearly uniformly as possible. In the work described this was accomplished by using a large cube—40 inches (1.01 m.) side—with its edges and corners filled. The result of this construction was a hollow figure of twenty-six sides each tangent to a sphere inscribed in the original cube. The interior of this was painted white and lit by a 100-watt lamp through a milk-glass which formed one of the oblique sides. The observer placed

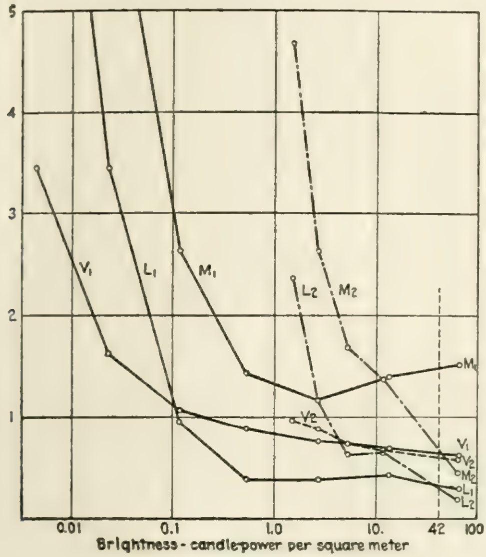

Fig. 1.—Variations in visual angle (V_1) and brightness-difference-perception (L_1, M_1) with absolute brightness of test-object, remainder of field is absolutely dark. And same (V_2, L_2, M_2) surrounding field at a brightness of 42 c-p. per square meter. Abscissae (brightness) plotted logarithmically, figures giving actual values. Ordinates in the case of visual acuity are plotted as visual angle in minutes, subtended by centers of adjacent dark and bright lines in test-object. In the case of brightness-difference curves the ordinates are actual differences per cent.

his face in an opening in one side and through an opening directly opposite him he looked at the test-field. The milk-glass through which the interior was illuminated formed part of the oblique surface over his head and outside of his visual field, so that he saw nothing but the white, illuminated inner surface of the figure and the test-field. With the eye under these conditions the experiments were repeated with known brightnesses of the test-

field, this latter being kept wholly independent of the illumination of the interior of the cube. The complete results are given in Fig. 1.

Any one who has ever attempted to determine the limiting value of a stimulus will know that the exact point of division between noticeability and the reverse is to be arrived at only as the properly determined mean of a large number of judgments. At or near the critical point it is very difficult to be sure whether one sees lines or not; or whether there is a difference in brightness or not, and if so what its direction is. The observer's verdict is in any one case obviously to a certain extent at the mercy of numerous minor influences, and of the state of his own mind. Further, if it were left to the experimenter's *ex tempore* judgment just what stimuli to present to the observer the result would obviously depend to some extent on the experimenter's prepossession in that respect. He would, unconsciously of course, be influenced to present stimuli at a time when he anticipated an answer from the observer that coincided with his own anticipations.

For these reasons, psycho-physicists have devised special methods for such estimations. A detailed discussion of psycho-physical methods would be out of place here, but two cardinal points may be mentioned with a brief account of their application to the present work.

(1) After determining, by a few preliminary experiments, approximately how the results will come out, the method of experimentation is planned so as to be as free as possible from any arbitrary choice on the part of either the experimenter or the observer. The whole procedure is cut and dried and no detail left to judgment in the course of the work if it can possibly be planned beforehand.

(2) When unavoidable circumstances (such as whether lines are shown to the observer the first or last half of an experimental session) would probably influence the result, the individual series of observations are so grouped that one half will be influenced one way, the other half the contrary way, and the distortion will hence average out. The work has to be so planned,

of course, with respect to every circumstance that may alter the result.

(1) The single series of observations consisted of sixteen exposures or stimuli. In the case of lines, for example, the finest shown in any one series were distinctly too small to be seen under the test-conditions, the coarsest distinctly visible, and the fifteen steps between represented a series of equal intervals from the one to the other. These sixteen stimuli were shown to the observer in haphazard order, previously determined by lot, and the observer's judgment rendered as positive, negative, or doubtful, as to visibility of the lines, and recorded.

Similarly, in the case of brightness difference of the two halves of the field, the two extremes of each series represented distinct difference in either direction (right half brighter or darker than left) with equal intervals between.

(2) Each session consisted of four series for each of the two observers, the other being experimenter at the time. The four series were: two brightness-difference series, one judged as to the right side, one as to the left, and two series of visual acuity judgments. It is in the making up of a session such as this that factors enter which might have a very serious influence on the result, *i. e.,* (*a*) whether observer A came before or after B, (*b*) whether he was shown lines before brightness-difference or after, and (*c*) whether he judged left or right side first (in the case of brightness-difference only). The entire set was therefore carefully and systematically planned so that A and B came first each in an equal number of series, lines and brightness-difference sharing precedence in a similar way, and in the case of brightness-difference, judgment on the right and left side each came first in just one half of the series.

The various intensities of the test-field also had to be distributed each in a fairly representative way over the whole period of the complete set, in order that any changes in the eye that take place over the entire period of weeks or months may take effect alike on the observations at all the intensities.

The interpretation of the results given in the curves is as follows:

Visual acuity (V) is plotted as the smallest visual angle in

minutes (from the center of any black line to the center of the adjacent bright line) under which the lines can be distinguished.

Brightness difference is plotted as (L) the limen, that is the difference per cent. which, by inference from the results actually obtained would be correctly recognized in just one half of the cases in which it was presented to the observer, and (M) the average difference at which in each series the first deviation from "correct" judgment occurs.

The results given are the means of all the observations of the two observers in each case. In spite of the precautions outlined, the curves in the figure show certain apparently erratic variations. Whether these are essential or accidental does not appear.

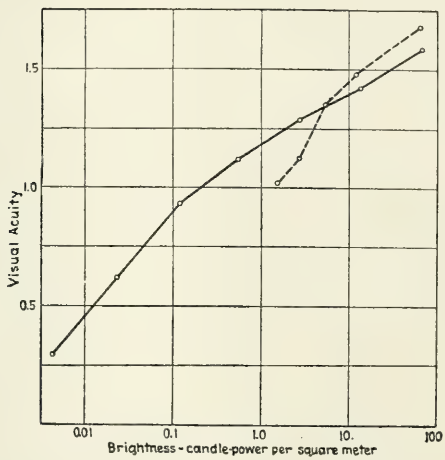

Fig. 2.—Visual acuity curves derived from the same values as V_1 and V_2 in fig. 1.

The only way to determine that point would be to multiply the number of experiments. The results given do, however, show clearly enough certain features.

The rapid increase in the least noticeable difference at very low intensities as shown years ago by Koenig, comes out clearly in the curves M_1 and L_1 (dark background) as also the low value for visual acuity (large visual angle) at low intensities (V_1).

When the bright background is used the lower limit of vision is evidently pushed up to a much higher intensity as definitely shown in M_2 and L_2, and intimated in V_2 by its altered trend.

By far the most striking point in the whole work is, to the writer's mind, however, the fact that by all three criteria used, vision at the highest intensity of test object shows a distinct improvement in the presence of the bright visual field, *i. e.,* vision is actually improved by filling the visual field with surface almost as bright as the test-object. The curve showing the visual angle translated into visual acuity (Fig. 2) brings this out more clearly.

Under certain circumstances then, the eye can see more clearly when a large amount of light falls into it than when this is cut off, or in other words, the eye can see equally clearly under those circumstances with a smaller amount of light on the test-object. That is, what has been called the "efficiency of the eye" is in some cases greater with a relatively large amount of light coming to the eye not from the test-object.

DISCUSSION.

MR. L. B. MARKS: It has been found in practise that an extremely concentrated lighting field with a dark background produces visual fatigue. Numerous cases of this kind have come to my notice in connection with factory and other lighting work.

In considering wall color and brightness of objects within the field of view, one must take into account the actual intensity of illumination and the ratio of intensities. In Dr. Cobb's analysis, for example, if we take very low intensities it might easily follow that a darker wall would be preferable to a lighter one, while if we take the higher intensities, the lighter wall would be preferable.

MR. J. R. CRAVATH: The point which interests me especially in Dr. Cobb's paper is that of the value of illumination on the background; namely, 42 candle-power per square meter, is a value which is frequently attained in practise on light colored walls. We would have good reason to suppose, with the information which the paper gives, that we would have higher visual acuity under practical working conditions with such rather highly illuminated walls. Dr. Cobb does not attempt to explain why this is so. It has been suggested that the diameter of the pupil is less where we have bright surroundings and therefore we are able to focus more clearly, just as we get a clearer image in the camera with a small aperture.

Dr. H. E. Ives: I have a little fact to bring forward in line with Dr. Cobb's research, in connection with the photometry of lights of different colors. You may have noticed that in my paper this morning I recommended that the photometric field be surrounded by a larger field of equal brightness. I did not go into details in my abstract this morning in regard to that, but I might enlarge upon it now.

In comparing lights of different colors by the equality of brightness method, I found by experiment that the presence of bright surroundings to the photometric field resulted in the range of settings being approximately divided by two; in other words, the sensibility was enormously increased.

As regards the question of fatigue, it has been my experience that the eye becomes very much fatigued looking down the black tube of the ordinary optical instrument at a bright field; on the other hand, using a bright tube, one could work very much longer. There was really a tremendous difference. In the paper this morning this observation was incorporated and the reason given is that it makes for the comfort of the observer. I am giving this for what it is worth. My own interpretation of it is that bright walls are not quite as black as they have been painted.

I do not think any difference in the diameter of the pupil would explain the differences found in the discrimination of shade differences, which show the same characteristics as the visual acuity tests.

Mr. H. P. Gage: I would just like to say a word about the last part of the paper, where Dr. Cobb shows that it is possible to detect differences in brightness and fineness of detail with a brighter surrounding field than with a dark surrounding field. I think this is due to the fact that the eye is able to focus accurately on the test object, whereas with a dark surrounding field, the eye is out of focus and the object is not seen clearly.

Another point, a little outside of this, was brought out by the use of the acuity method, showing that a monochromatic light will give a higher acuity than white light. This has been pretty well recognized as due to the chromatic aberration of the eye. It would be very interesting to try some of these tests, using a glass in front of the eye designed to make the eye an achromatic instrument. The normal eye at rest will be found to be in focus

for the red end of the spectrum, if the eye is correctly focused for a red light and it will be found that for blue or green light, the eye will be short-sighted. This has an important bearing on signalling.

The other night I had a negative lens and I took occasion to examine the lights from the rear of a train (red, green and yellow). It was interesting to note the greater range at which the red light could be seen under the ordinary conditions of the eye at rest. With the negative lens, which renders the eye far-sighted, the green light, which appeared as a bright point with rays around it, was brought down to a definite round spot and could be seen at a much greater distance than without the glass. This indicates the reason why different people, not color blind, will get different appearances with the same colored signals.

In signal work, not only the question of color sensitiveness and color blindness enters into consideration, but also the dioptric condition of the eye whether near or far-sighted and, if normal, for which particular wave-length the eye is in focus when at rest.

MR. M. LUCKIESH: The data given show that under the conditions of the test, better results are obtained amid bright surroundings when the brightness of the object is 10 to 100 candle-power per square meter. The bright surroundings were not any brighter than those very often found in actual practise.

In regard to fatigue: the periods of the test were about 45 minutes long for the observer. This is not considered by psychologists to be long enough to induce undue fatigue. In fact Dr. Cobb's data do not show any effects of fatigue when the data of the first and last halves of the period are compared.

The question of better acuity in monochromatic light was quite thoroughly thrashed out at the convention of the Society last year.

DR. P. W. COBB (in reply): Referring to Fig. 2—at the level where visual acuity is 1.5 the bright surroundings evidently from the (dotted) curve gave the eye an advantage, since vision maintained this value with a less bright test object than was necessary in dark surroundings. That is, the "efficiency of the eye" was greater than unity—in fact (bearing in mind that we are using a logarithmic abscissa-scale) the "efficiency of the eye" estimated

from the curves would be here about 2.00. At 5 candle-power per square meter (about one-eighth of the surrounding brightness) the two curves cross—which means that this value is here unity, and below this point it is less than unity. It could evidently be made almost indefinitely small by selecting a low enough test-object brightness to start with. The curves show it to be about 0.15 at the lowest point given (visual acuity a trifle over 1.0).

I would add that the visual acuity values came out much more consistently and definitely than the brightness-difference values and are hence much more trustworthy. However, as the curves show, the change in conditions works a relative change in results in every case of the same direction as that seen in the case of visual acuity.

I admit that a more thorough investigation of the matter in the region of higher brightness is desirable as far as the M and L curves are concerned. That is easier seen than foreseen. Each point in the figure indicated by a small circle is the result of 512 (in a few cases only 448) separate judgments, each pronounced after 3 seconds observation of the test object. The entire work of which these are the final results extended over the larger part of a year.

In reply to Dr. Gage, I would say that the surrounding surface was 1 meter distant, while the test-object itself was 2 meters from the eye. In view of this, accommodation for the test-object should be more disturbed when this latter was lit up. There was no evidence whatever of any difficulty of this kind. The blank field was always present to the eye before the exposure, having borders identical with those of the test-field which served as a guide to the eye in accommodation.

The observation cited by another speaker is interesting. The conditions in the case he mentions (light from a source directly upon the eye) are not the same as an equal number of meter-candles coming from an extended and uniformly bright surface to the eye. As a matter of fact, working with the brightest test-object on a dark field produced considerable discomfort and vaguely uncertain feelings referable to the eyes, which did not appear in the presence of the bright surroundings.

It is exactly such ideas as those that Mr. Marks has just expressed that have made this work appear to me to be worth

while. Nature, rarely if ever, treats man to an extreme local type of illumination. We must bear in mind that sunlight is about one thousand times as intense as ample artificial illumination; so I do not feel that the brightness chosen for the background in this work is at all abnormal to the eye, although it may not fall within the limits of engineering practise.

Replying to Mr. Cravath: I have preferred in this paper to give the results without going into the theory of the matter. A smaller pupil does not necessarily mean more distinct vision except where the refraction of the eye is imperfect. In my own eye (moderate astigmatism, corrected) I found by using a set of artificial pupils that visual acuity grew markedly less with decrease in pupillary size below 3 mm., even when the brightness of the test-object was raised to compensate exactly the decrease in pupillary area. And further, the M and L curves, Fig. 1, show changes in the same direction that visual acuity does, and it is fair to suppose that exactness of the retinal image plays at most a much less significant part in the estimation of brightness differences in visually gross areas. I do not wish to be understood, however, as saying that the pupillary diameter has been eliminated as a factor. I do feel that other things are necessary for a full explanation.

There is in progress at the laboratory with which I am connected further work of similar character to this, using a brightness of 3 candles per square meter for the surroundings instead of 42, which it is hoped will make the entire question more clear.

A PRACTICAL SOLUTION OF THE PROBLEM OF HETEROCHROMATIC PHOTOMETRY

BY PROF. CH. FABRY.

Synopsis: In order to reduce all practical photometry to that of lights of the same color, secondary standards of various colors or colored absorbing media are necessary. These should be calibrated in the standardizing laboratory, by the most refined methods of heterochromatic photometry. The calibration of an infinity of colored standards, or of every individual colored glass, is not practical. Herewith are described absorbing liquids, definitely specifiable, which may be used in varying thicknesses and proportions to make the light of a given standard like that of any other illuminant. A yellow and a blue solution have been found which suffice to match with a Carcel, all the ordinary illuminants; a purple solution is suggested for use where these are not sufficient, the three absorptions giving, by the three-color principle, all the tints as represented in a color triangle. The method of use of these screens is outlined, the possible methods of calibration are described and some experimental results are tabulated.

In spite of many good works, the problem of heterochromatic photometry seems not to be satisfactorily solved for practical use. In the comparison of two lights of very different colors, as, for instance, an incandescent carbon lamp, used as a standard, with daylight or the mercury-vapor arc, there remains a large amount of uncertainty and arbitrariness. Several very good papers, published in these TRANSACTIONS, especially by Dr. Ives, have forwarded the question. Probably the definitive solution will be conformable to the suggestion of Dr. Ives[1] namely: Measure every simple radiation in quantity, by the energy conveyed by it in one second, an operation entirely independent of the properties of the human eye; then, quote every one at its proper value for the special application to lighting, this value being *zero* for all infra-red or ultra-violet radiation. Thus, for computing the value of some ore containing metals of different prices (gold, silver, copper, etc.) one will determine the weight of each metal, and each one will be quoted at its proper price, sand and stone being quoted at zero for metallurgic purposes.

For this definitive solution we are not yet ready, at least for

[1] TRANSACTIONS of the Illuminating Engineering Society April, 1911, page 258, and *Astrophysical Journal*, November, 1912, page 322.

everyday use. Meanwhile, we are obliged to choose some provisional solution, and a French proverb says that nothing lasts longer than a makeshift. It is moreover possible that a provisional solution could be turned into a definitive one when it will be possible to properly express the experimental results.

In actual practise, we cannot think of making a complete analysis, qualitative and quantitative of every light to be measured. So long as the eye will be used in photometric measurements, the equalization of two illuminations on the photometric screen is all that can be asked for the ordinary observer, and this equalization can be accurately made in only one case, *i. e.*, when the lights are of the same color. We are thus led to eliminate from practise any heterochromatic measurement, as was excellently expressed by Dr. Ives:[2] "I think it extremely important—it is essential—that in ordinary photometry there should never be made a comparison of different colors. All practical photometry should be reduced to photometry of the same color. Consequently, the question of which photometer is to be used for comparing lights of different colors, becomes a question for the standardizing laboratory, the Bureau of Standards, the Reichsanstalt or the National Physical Laboratory."

What have we to do in order to reach this end, viz., to have only comparisons between lights of the same color? We cannot hope to find as many different standards as there are different tints, *i. e.*, an infinity: the difficulties encountered in finding one good standard do not encourage one to search so large a number.

With a single photometric standard, the only chance of success is to modify its tint by interposition of some apparatus in the beam of light, in order to give it the desired color. This change of color will at the same time modify the intensity in a ratio which will be measured once for all in every case; this measurement, unavoidably involving heterochromatic measurement, will be made by the standardizing bureau.

There are many means at the hand of physicists by which the tint of a complex radiation, *i. e.*, the proportion of the different simple radiations in the light under consideration, may be

[2] TRANSACTIONS of the Illuminating Engineering Society, November, 1910, page 727.

changed at will.[3] From a practical standpoint, the simplest means is the interposition of some absorbing medium. The use of such absorbing substances (colored glasses) has been suggested and actually tried.[4] The procedure is as follows: We have, for instance, to compare an electric arc with an incandescent lamp used as a standard; when the two parts of the photometric screen are illuminated by the two sources, they appear very different in color, and the equalization of brightness is largely a matter of judgment. On the incandescent lamp a blue glass properly chosen is superposed, which absorbs the excess of red and yellow light contained in the radiation of this lamp, and gives it the same color as that of the electric arc. The equalization of illumination on the photometric screen will then become easy and precise. By this procedure, we are able to compute the intensity of the arc lamp if we know how many candles the incandescent lamp gives through the blue glass. As we know the intensity of the lamp without the absorbing glass, we need only to have the ratio between incident light and transmitted light through the glass, *i. e.,* the *opacity* of this glass for the total radiation of this lamp. The opacity can be measured once for all, but this value is right only for the glass employed and for a lamp giving the same kind of radiation as the lamp used for the measure. If a higher voltage is applied to the lamp, the proportion of blue radiations freely transmitted through the glass will be greater, and the opacity will be less. The measure of these opacities for fixed light would be the problem of the standardizing Bureau, and as it is probably impossible to reproduce glasses exactly, it would be necessary to make the measurement on every separate sample of glass, of which a great many would be necessary to match the color of the different sources now employed in practise.

An important step would be reached if it were possible to use

[3] All these means work by inequal weakening of the different simple radiations; they are incapable of adding simple radiations lacking in the considered light. If this was monochromatic, any one of these means could not change its composition. We consider, in fact, as standard source, such a source as giving forth a mixture of every simple luminous radiation. In such a case, it is conceivable that, by proper weakening of the different simple radiations, it would be possible to get every possible mixture of simple radiations, *i. e.*, every possible light.

[4] Ives, TRANSACTIONS of the Illuminating Engineering Society, November, 1910, page 728; Cady, October, 1912, page 385.

definite absorbing media, reproducible by every observer; the opacities of different thicknesses might be measured once for all, and every observer would be able to use these values, without purchasing a definite object measured at the bureau. The light used for these measures of opacity should be of definite composition, but it need not be the light of a standard of intensity; it is possible, and perhaps better, to separate the two duties, in order to choose the best standard for each purpose; the standard of intensity ought to have a fixed intensity, and a very small change of tint from one standard to another is of no consequence; the standard of color must give a radiation of constant composition, but a change of intensity from day to day is absolutely unimportant because it will every time be compared with the standard of intensity.

These thoughts came in my mind ten years ago, and I made a long series of experiments to put them into practise. Some physicists to whom I showed my results raised many objections, from which I concluded that the theory of colors was not yet sufficiently understood to permit the general use of my method; I published only a short article,[5] which was entirely unnoticed. The situation is now changed,[6] and I think it is now worth while to publish a more complete account of my experiments, in the hope of contributing to the improvement of the methods of heterochromatic photometry, which are still in a somewhat chaotic condition.

I suppose the question of the standard of intensity to be solved. In the practise of to-day, the standard is not a flame, but an incandescent carbon lamp which, at fixed voltage, gives a definite number of candles.

Furthermore, I chose a source giving light of definite tint, without respect to intensity, which need only remain constant during the short time of the measure. I have chosen the old Carcel

[5] *Comptes-Rendus de l' Académie des Sciences*, 9 Novembre, 1903, (Sur une solution pratique du problème de la photométrie hétérochrome).

[6] If, today, the technical men are better prepared to understand the problems of heterochromatic photometry, that is in a large degree owing to the works published by the Illuminating Engineering Society; it is for that reason that I have wished my paper to be published in these TRANSACTIONS, the readers of which are the best prepared to grasp the problem here dealt with.

lamp,[7] which is probably good enough for this very simple service; perhaps a carbon incandescent lamp at a fixed number of watts per candle would be more convenient. The light of the Carcel is very similar to that of the carbon lamp ordinarily used as standard of intensity, but is very different from many other lights, especially from the light of the sun.

I have sought such colored substances as, interposed in the light of the Carcel, will give it the color desired in every case. To have reproducible absorbing media, whose opacity can be measured once for all, one is lead to use liquids of definite composition and proper thicknesses. It is desirable to be able to get every possible tint, in order to match the color of the standard with that of each light. A single liquid is not sufficient to arrive at this end; if only one liquid is used, only one variable is at one's disposal, viz., the thickness of this substance or, what is

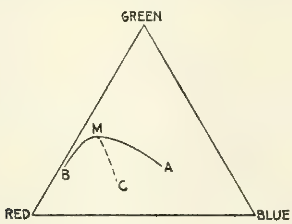

Fig. 1.

the same, the concentration of the absorbing dye in mixture with an uncolored liquid as water. A single set of colors can be thus obtained; if every tint is represented by a point in the triangular diagram of Maxwell-Koenig,[8] the different tints produced in varying the thickness will be represented by the different points on the curve A (Fig. 1) beginning at the point M which represents the tint of the Carcel without the absorbing medium (thickness *zero*). Only the colors represented by some point on the curve A can be matched by the use of the Carcel with the absorbing medium under consideration.

Another liquid of different color will give another set of tints

[7] I did not use the Hefner lamp, on account of its too red color, and because it is too weak when further weakened by absorption. The light of the Carcel is so similar to that of the carbon incandescent lamp at normal voltage that the values given below would probably be applicable without change to this latter source.

[8] For the definition of this diagram, see: Ives, TRANSACTIONS of the Illuminating Engineering Society; April, 1910, page 205, and April, 1911, page 266.

represented on the diagram by the different points on another curve B beginning at the same point M.

If two absorbing cells are used, one of the first liquid and one of the second, we have at will the values of two variables, the thicknesses of the two cells; it will be possible to obtain all the tints represented in a certain part of the diagram. We cannot cover all the surface of the diagram, but, at least, a finite surface of it. If the two liquids are properly chosen, we can hope to match exactly the light of many of our ordinary sources.

The two liquids chosen are one of blue color, with absorption increasing from violet to red, and one yellow with absorption varying in the inverse direction. The aim to have liquids definite

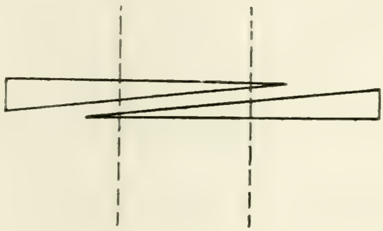

Fig. 2.

and reproducible leads us to set aside all the anilin dyes, and to seek only among the mineral substances. The two liquids chosen were:

A. Crystallized copper sulphate.................1 gram
Commercial ammonia (density 0.92)......100 cubic centimeters
Water, quantity sufficient to make 1 liter

B. Potassium iodide .... 3 grams
Iodine .... 1 gram
Water, quantity sufficient to make 1 liter

The thicknesses of the cells containing each of these liquids can be varied at will; I shall denote by x the thickness of the blue liquid A and by y the thickness of the yellow liquid B, the two expressed in millimeters. The thickness can be varied at will if, for each liquid, a double wedge shaped cell is used (Fig. 2); when one of the wedges is slid, the total thickness of the liquid can be varied continuously. It is ordinarily simpler to leave constant the thickness, using a parallel cell, and change the concentration of the liquid; I have verified the fact that a change in

concentration produces the same effect as a change of thickness (Beer's law); x and y are then the products of the thickness measured in millimeters by the number of grams per liter (copper sulphate or iodine) in the solution used. In this change of concentration, one must leave approximately unchanged the proportion of ammonia contained in the liquid A, and consequently add to this liquid not pure water but water containing ammonia in the proportion of 100 cubic centimeters to the liter. For the liquid B, pure water can be added. I ordinarily use cells with parallel faces and of 20 millimeters thickness.

With these two absorbing media of proper thickness and concentration, and the Carcel lamp used as standard of color, it will be possible to match the color of almost every source used in practise. With a single cell containing the liquid A ($y = 0$) we obtain, with increasing thickness (x greater and greater) light of color more and more blue; we can match in this way the color of every source similar to the black body at higher temperature than the Carcel, including the solar light. The tints produced in this way are represented in the diagram (Fig. 1) by the different points on the curve A. With a single cell filled with the liquid B, by increasing the thickness or concentration of this liquid ($x = 0$, y increasing), we obtain lights of more and more yellow and finally a red tint; the colors so obtained are represented on the diagram by the curve B. Using the two cells with every possible thickness or concentration (x and y varying at will), we can produce light represented to the left and above the curve AMB, viz., all the set of blue, green, yellow or red tints, more or less saturated. We cannot get the tints represented to the right and under AMB, *i. e.*, the purple tints, in which are predominant the radiations of the two ends of the spectrum with weakening of the middle part; a third liquid, used with one or the other of the two just described, would be necessary in order to get these tints. I did not think it worth while to seek such a liquid.

For every source of light we have to search for the values of x and y necessary to match its color. The following table gives some values.[9]

[9] These values are given here only as an indication, inasmuch as the indicated sources are by no means in themselves definite in color.

Source of light	x (Blue solution)	y (Yellow solution)
Ordinary carbon arc (not mineralized)	33	0.0
Tungsten lamp	10	0.0
Acetylene flame	12	0.0
Incandescent carbon lamp at $^2/_3$ of its normal voltage	0	5.4
Id. at $^3/_2$ of its normal voltage	19	0.0
Hefner lamp	0	1.5
Auer light	41	1.0
Nernst lamp	22	0.6
Cooper-Hewitt lamp	76	0.6
Sun at noon in summer	54	0.0

As can be seen, the blue solution is, in most cases, the most important, and indeed in many instances, must be used alone to produce the desired tint. It is the case for all sources of light whose spectrum is similar to that of a black body at higher temperature than the Carcel (tungsten lamp, electric arc, acetylene, sun). The precision with which these sources of light can be matched by means of the Carcel and copper liquid is really surprising. The tint of the sunlight, so greatly different from that of the Carcel as to render almost photometric comparison impossible, is practically indistinguishable from the color of the modified Carcel.[10] That does not prove that the energy curves of these two lights are entirely identical, but the energy curve of the so modified Carcel is much more like that of the sun than is the energy curve of the natural Carcel, as is to be seen from Fig. 3 where are represented the energy curves of the Carcel lamp, of the same source through 54 millimeters of copper solution and that of sunlight. For a normal eye the two last tints are identical, and it is probably so for every eye not entirely abnormal. The white stars (like Vega) give a light still more blue than that of the sun; they could probably be matched with the Carcel light by using a somewhat greater thickness of the same liquid. For the explanation of this property of the copper solution, see later (appendix).

The interposition of colored cells in the radiation of the Carcel

[10] I have many times used the light obtained in this way for works of astronomical photometry (determination of the candle-power of the Sun, comparison of the light of the Sun with that of the Stars, etc.).

lamp does not only change its color; the intensity is also weakened. We must know this change in order to use our absorbing media in photometry. The weakening is partly produced by reflection on the faces of the cells, and partly (the greatest part) by absorption in the liquids. In order to eliminate the effect of reflection, we shall compare the intensity of the Carcel through cells filled with pure water with the intensity through the same cells containing the liquids; the ratio of the first number to the second will be called the opacity of the liquids. This opacity is a perfectly definite function of the two quantities x and y which characterize the conditions of the two media. It is possible to investigate it once for all, and get a numerical table or an empirical formula giving the values of the opacities for every value

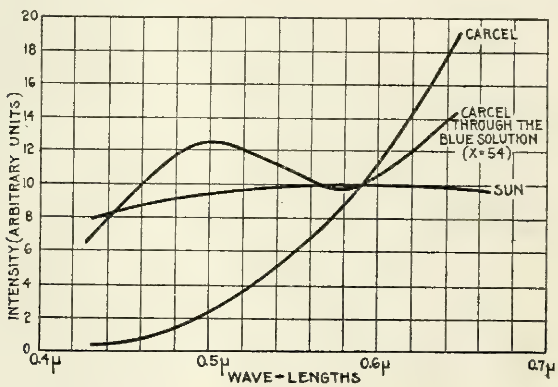

Fig. 3.

of x and y. The experiment necessary to get the numerical values of the opacity are, unavoidably, heterochromatic photometric measurements; they ought to be made with the most refined methods of heterochromatic photometry and, if possible, by several observers, to have the most probable values for a normal observer.

I made some such measurements in 1903; they were not published. I will give here my results, but I do not claim for them great accuracy: the method used was that of equal brightness, with the use of the Lummer-Brodhun photometer (the flicker photometer was not yet in general use); perhaps the brightness of the photometric screen was not great enough to eliminate the

complications arising from the Purkinje effect, which leads to over-estimates of the intensities of blue lights; the measurements were made only by one observer. I have some reason to think that the values given for opacity of the blue solution were rather too low. Be that as it may, I have found that the opacity for thickness x and y of the two luiquids is expressed by the following empirical formula:[11]

$$\log \text{opacity} = 0.016\, x + 0.032\, y - 3 \times 10^{-5}\, x^2 + 6 \times 10^{-4}\, xy \qquad (1)$$

The following table gives some values computed from this equation:

		Opacity			Opacity
0	0	1.00	0	1	1.08
10	0	1.44	0	2	1.16
20	0	2.02	0	4	1.34
30	0	2.97	0	6	1.56
40	0	4.0	10	1	1.57
50	0	5.4	20	2	2.49
60	0	7.3	40	4	6.55
			60	6	18.2

The values of the opacity being known, it becomes easy to reduce every photometric measurement to comparisons of the same color. Suppose we have, for instance, to measure the intensity of an electric arc in terms of an incandescent carbon lamp used as standard of intensity. We will first seek what thickness (or concentration) of the two liquids must be interposed in front of the Carcel to give to its light the color of the electric arc; we will find that we must have no yellow cell, and, for the blue one, a thickness or concentration defined by $x = 33$. On the other hand, the incandescent lamp has almost exactly the same tint as the Carcel; we need not change the color to compare these two lights. On the photometric bench we put on one side the standard lamp, on the other side the Carcel, interposing the cell to be used later, filled with water; the equalization of the two intensities will be made. Instead of the standard lamp we put then the arc to be measured, and we fill the cell placed in front of the Carcel with the proper blue liquid; we equalize once more the illuminations, which are still of the

[11] For the derivation of this formula from a theoretical standpoint see appendix.

same tint. The opacity of the used liquid being known, the computation of the intensity of the arc is easy.

This procedure is scarcely more complicated than the ordinary measurement with lights of the same color; it is true that we must equalize twice the illuminations on the photometric screen, but it is ever so when the double weight method is used and the use of this method is generally to be recommended. If we have many measurements to be made with the same kind of light, the same liquid will be used. Perhaps, in this case, it will be found more convenient to use some colored glass properly chosen, if such a glass can be found; it will be easy to measure the opacity of this glass by comparison with the known liquids, without going to the standardizing bureau, and by making comparisons of nothing but lights of the same color.

It is worth remarking that the standard color lamp (Carcel for instance) with the absorbing liquids gives us an arbitrary scale of tints whose use is very convenient and quite inexpensive. True, this scale is quite arbitrary, but from the data so obtained for a light, it is always possible to pass to the tint expressed in absolute value, *i. e.,* the values of fundamental sensations contained in the studied light, or the point which represents it on Maxwell's diagram. In some cases where the other methods are difficult to use, perhaps this procedure could give some useful information; it would be perhaps so in some astronomical observations.

As was said, the use of two liquids is not sufficient to produce every possible tint; with the two liquids chosen, we can only get the tints represented above the curve AMB (Fig. 1). With a third liquid we could get every possible tint. The liquid to be chosen ought to be purple, absorbing the middle part of the spectrum more than the two ends; this medium, taken alone with increasing thickness would give tints represented by such a curve as MC. On combining this liquid with the blue liquid A, it would be possible to have every tint represented by points in the angle AMC; the same liquid in combination with B would allow us to cover the angle BMC. In short, we should have three liquids giving respectively, when employed separately, the curves MA, MB, MC; combinations of two liquids allow the

production of every possible tint. Perhaps a solution of potassium permanganate would be good as a third liquid.[12]

The absorption methods in optics have been often criticized, and sometimes rightly, because many incorrect results have been noticed on account of an incorrect interpretation of the facts. Certainly, the use of absorption, which does not allow the complete separation of simple radiations, demands a critical attitude on the part of the inventor; but, when the methods are properly tried out, this process leads to very simple experimental devices, which is of first importance from a practical standpoint.

APPENDIX.

I will collect here some calculations and numerical data not necessary for the practical use of my method, but useful for its comprehension.

I have investigated the absorption curve (absorption as a function of the wave-length) of my liquids. The measurements were made by use of a spectrophotometer, without seeking for a great accuracy, but in order to find the behavior of the phenomenon.

Let us consider the liquid A (1 gram crystallized copper sulphate and 100 cubic centimeters ammonia in 1 liter), and take it with a thickness of 1 millimeter ($x = 1$). For a simple radiation of wave-length λ, this cell has an opacity ω (ratio of the intensity transmitted through water and intensity through the cell). Instead of ω it is often more convenient to characterize the absorption by the decimal logarithm of ω, called the absorption constant α:

$$\alpha = \text{log opacity} = \text{absorption constant.}$$

If the cell has a thickness x the value of the absorption constant for the same wave-length will become αx.

For the liquid B (1 gram iodine and 3 grams potassium iodide in a liter) in thickness of 1 millimeter ($y = 1$) the similar quantity will be denoted β.

Fig. 4 gives the values of α and β plotted against the wave-length.

If we have to investigate the action of these absorbing media on the light of the Carcel, we must know the luminosity curve

[12] The use of the third liquid would probably be necessary to match the color of certain flaming arc. I did not make experiments on these sources.

of the spectrum of its light. We can admit that the radiation of the Carcel lamp is identical with that of a black body at a temperature a little under 2,000 degrees of the absolute scale; its light is not so yellow as that of the Carcel, but not so blue as that of the acetylene flame. We can therefore trace the curve which gives, as a function of the wave-length λ, the intensity I measured by the quantity of energy carried in one second (energy curve of the Carcel). On the other hand, we know the sensibility curve of the eye as a function of the wave-length[13]; let us denote by δ the sensibility of the eye for the radiation λ;

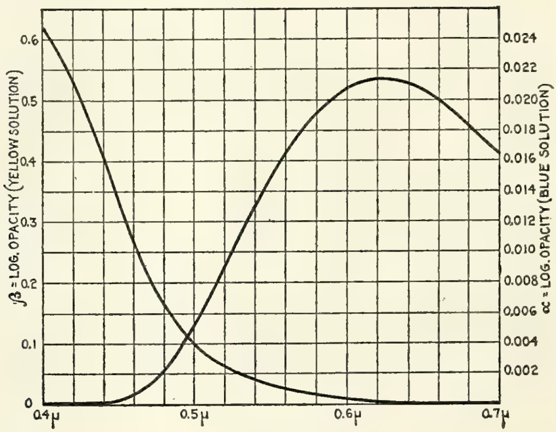

Fig. 4.

the values of δ are proportional to the luminous intensity at equal energy value. The product $L = I\delta$ is the luminous intensity (in arbitrary units) for the radiation λ, and we can trace the *luminosity curve* of the spectrum of the Carcel.

We put in front of the Carcel the thickness x of the blue liquid; the opacity of this cell for the radiation λ is $10^{\alpha x}$; this radiation, whose luminous intensity was L will be reduced to $L \times 10^{-\alpha x}$. It will be easy to trace the luminosity curve of the light so modified.

In order to have the opacity of the cell for the complete light of the Carcel, we must compare the total intensities without and with absorption. In the first case, the total intensity is:

[13] See, for instance: Ives, TRANSACTIONS of Illuminating Engineering Society, April, 1911, page 261, and October, 1912, page 379; or *Astrophysical Journal*, November, 1912

$$\int L d\lambda.$$

With absorbtion, it is:

$$\int L 10^{-\alpha x} d\lambda.$$

The opacity Ω, ratio of the first number to the second, is:

$$\Omega = \frac{\int L d\lambda}{\int L 10^{-\alpha x} d\lambda}.$$

A similar calulation will be applied to the liquid B.

If we use the two liquids A and B, we will find for the opacity:

$$\Omega = \frac{\int L d\lambda}{\int L 10^{-(\alpha x + \beta y) d\lambda}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

As the values of L, α and β are known for every value of λ, we can compute the values of the opacity for every value of x and y. The integrals are computed graphically, and that is not difficult if one uses a planimeter.

I have made this numerical computation for some values of x and y. The concordance with experimental values given above is not perfect, but tolerably good, in consideration of the lack of accuracy of the numerical data used (luminosity curve of the Carcel, absorption curve of the liquids) and of the uncertainty of my heterochromatic measurements.

The equation 2 which gives the opacity as a function of x and y is not expressible by the elementary functions. We can express it by a development in series. The mathematical study of the question shows that the best way is to develop log Ω in increasing powers of x and y. Dropping powers of the variables higher as the second, we find:

$$\log \Omega = Ax + By + Cx^2 + Dy^2 + Exy.$$

The values of the co-efficients are:

$$A = \frac{\int \alpha L d\lambda}{\int L d\lambda} \qquad B = \frac{\int \beta L d\lambda}{\int L d\lambda}$$

$$C = 1{,}151 \left[\left(\frac{\int \alpha L d\lambda}{\int L d\lambda} \right)^2 - \frac{\int \alpha^2 L d\lambda}{\int L d\lambda} \right]$$

$$D = 1{,}151 \left[\left(\frac{\int \beta L d\lambda}{\int L d\lambda} \right)^2 - \frac{\int \beta^2 L d\lambda}{\int L d\lambda} \right]$$

$$E = 3{,}302 \left[\frac{\int \alpha L d\lambda \times \int \beta L d\lambda}{\left(\int L d\lambda \right)^2} - \frac{\int \alpha\beta L d\lambda}{\int L d\lambda} \right].$$

It can be proved that A, B and E are positive, while C and D are negative. The formula is of the same type as the empirical equation 1; the computation of the coefficients by the above formula gives values approximately in accordance with those empirically obtained.

Lastly, we can compute the color produced by a given thickness of the two liquids interposed on the Carcel, and represent every tint by a point on Maxwell's diagram. In this connection, I have above insisted on the precision with which the blue solution alone, interposed in front of the Carcel, can change its color in such a way as to give it the color of the radiation of any black body at higher temperature. To explain this property, we will examine the following problem:

The Carcel is supposed to have the same radiation as a black body at a temperature T (a little under 2,000 degrees). We wish, by a properly chosen absorbant, to modify its radiation in such a way as to give it the same composition[14] as that of a black body at a temperature T′ higher than T. What absorption curve must this absorbent have, *i. e.*, what is the relation between the absorption constant of the cell used and the wave-length?

[14] That is a sufficient but not necessary condition to have the desired color. If it is fulfilled, the tint will be the same for every eye, even not normal.

The problem is immediately solved if we know the energy curve of the two radiations, and these curves are defined by Wien's formula.[15] The opacity of the cell ought to be the ratio of the two intensities, multiplied by an arbitrary constant. We find thus that the absorption constant a (logarithm of opacity) must be expressed as a function of the wave-length by the equation:

$$a = 6{,}310\left(\frac{1}{T} - \frac{1}{T'}\right)\frac{1}{\lambda} + C^{te} = -\frac{A}{\lambda} + B.$$

A and B being two constants.

If we trace the curve giving the values of a as a function of $\frac{1}{\lambda}$ we must have a straight line. If such a substance is found. it will allow us to transform the radiation of a black body at temperature T into a radiation identical with that of a black body at higher temperature T^1; the thickness of absorbant to be used is proportional to $\frac{1}{T} - \frac{1}{T'}$.

Returning to our blue liquid, if we trace the curve giving its absorption constant as a function of $\frac{1}{\lambda}$, we have the curve in Fig. 5. That is not mathematically a straight line, but the curve has, in the brightest part of the spectrum, a very long inflection; the part MN, the most important for color, is almost linear. It is, therefore, not surprising that the *color* (not requiring absolute identity of energy curve) of the black body at any high temperature could be got by the use of our liquid. In fact, the thickness necessary to make the transformation is approximately given by the equation:

$$x = 16{,}500\left(\frac{1}{T} - \frac{1}{T'}\right).$$

The determination of the value of x necessary to match the color of the Carcel with that of a source of light gives us an indication of the temperature of this source, if it is similar to a black body.

[15] Planck's equation gives practically the same numerical values in the field of wavelength and temperature with which we are here concerned.

The black body's radiation having a peculiar importance in the science of illumination, substances having an absorption law expressed by the equation $a = -\frac{A}{\lambda} + B$ are peculiarly interesting for the problem of heterochromatic photometry. Perhaps it would be possible to find some other liquid fitting this law better than does my blue solution, but that is a matter of chance. Other means than absorption can be found to modify the intensities of different radiations (interference, chromatic or rotatory

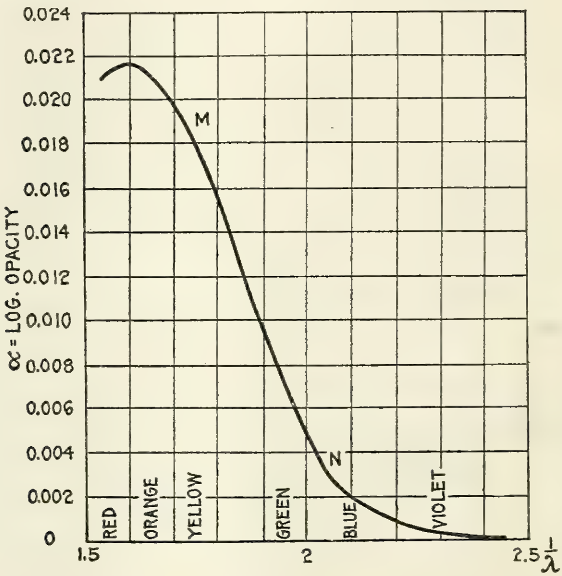

Fig. 5.

polarization), and they have, as against absorption, this advantage that the law of alteration can be computed *a priori;* but it does not seem possible to get by one of these methods the law of opacity expressed by the above equation. The only complete solution would be to separate the different simple radiations in a spectrum, then weaken these differently by proper screens, and finally recombine them. That is, of course, a very complicated procedure, and the use of absorption, in spite of its theoretically imperfect character, seems to be the only way to solve the problem practically.

DISCUSSION.

Dr. Herbert E. Ives (Communicated): The Illuminating Engineering Society has reason to feel honored by Prof. Fabry's selection of the Transactions for the place of publication of this admirable paper. His contribution is marked by a thorough grasp of the subject, by much insight and ingenuity in choice of the practical means for carrying out the central idea and as a whole constitutes a very positive addition to the progress toward practical colored light photometry.

The use of calibrated absorbing screens has, indeed, as Prof. Fabry states, been suggested before, but such suggestions have not been in the practical shape now proposed by him. They have tacitly involved the calibration of every screen sent out from the standardizing laboratory, not the calibration of a formula easily reproducible by anyone. This constitutes a great advance. One cannot but admire, too, the ingenious idea of making a universal absorbing screen by applying the three-color principle in the choice of absorptions. In general I should personally have been suspicious of this method through fear that different observers of different color vision would not find the standard screens to perform their color difference eliminating function completely. This objection is, however, very fully overcome by the choice for the blue-green element of a medium which alone is sufficient to perform by far the most usual transformation, namely, from one black-body color to another, by producing very nearly an exact spectral match, the same in appearance for all eyes.

Up to the publication of this paper it has happened that most attention has been given, by workers in this field, to study aimed at establishing methods for calibrating different colored standards. As is clearly stated by Prof. Fabry, the actual practical use of his absorbing screens is dependent upon the development and adoption of such methods of calibration. In view of the recent progress in clearing up the characteristics of different photometric methods, Prof. Fabry's screens come before us at a most opportune time.

It may be of interest to outline here the work along this line which is now being done in the physical laboratory of the United Gas Improvement Company, especially as the new absorbing

screens will take a prominent part therein. The work in general consists in the calibration, by several different methods, of standards and absorbing screens for use in practical photometry. All of these methods are developments of, and in conformity with, the results of the writer's published work on heterochromatic photometry. In short, the flicker photometer, under the conditions specified in the writer's paper before the Society at the 1912 convention, will be the standard instrument, and the visual luminosity curve determined by its use will be taken to represent the normal eye. The first line of attack is through the use of a special flicker photometer, now under construction, embodying all the features called for by the previously mentioned work. Auxiliary standards and absorbing screens will be calibrated through observations by a large number of observers. The problem of selecting absorbing media to be calibrated is obviously enormously reduced by the timely appearance of Prof. Fabry's work.

A second line of attack is by application of the spectrum absorption curve of the various media to the normal visual luminosity curve in the same manner that Prof. Fabry has indicated. Great accuracy is aimed at. The spectral absorptions will be determined by the aid of the photo-electric cell, which promises to greatly excel the eye for sensitiveness in spectrophotometry. In all cases of calibrating screens they will be used with the standard 4-watt lamp as maintained at the Bureau of Standards, perhaps also with the standard Pentane lamp and the Hefner.

A third method of attack is through the photo-electric cell of one of the alkali metals, properly screened so as to have the sensibility curve of the eye. Experiments toward this end are being actively carried on.

It is only in one line of work that calibrated absorbing screens might be found inconvenient, namely, in laboratory tests of incandescent mantles of varying compositions or electric incandescent lamps of varying efficiency. To facilitate this kind of work it is my present idea to use the special flicker photometer with absorbing screens which will correct each observer's eye to normal. Study of a set of luminosity curves of 18 observers has shown that practically all these observers can be corrected to

normal by a yellowish or bluish screen placed over the eye. Given two colors (such as solutions) which should measure equally bright to a normal observer, and two solutions showing absorption curves of long gradient, it should be possible for every observer in a laboratory to be equipped with a screen to carry on normal heterochromatic measurements.

All of this work will be reported in due course. It is mentioned here in order to indicate the prospects that before long the measurement of different colored lights will be in practical shape, both through the accurate calibration of Prof. Fabry's ingenious screens and by other means.

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Pittsburgh Convention.

The seventh annual convention of the Illuminating Engineering Society was held at the Hotel Schenley, Pittsburgh, September 22 to 25, 1913. A program of excellent papers, which occasioned many spirited and interesting discussions, a comparatively large attendance and a generous complement of entertainment combined to make this meeting a pronounced success. In the history of the society it marks another gain in the rapid progress made by the society within the seven years of its existence in the promotion of the science and art of illumination.

The registration totaled 459 members and guests. It is probable, however, that the attendance reached approximately 500. Of the latter number 176 were members. The average attendance at each session was approximately 100.

A prize, an ornamental desk lamp, was won by the New York Section for having the largest representation at the meeting.

Several of the papers and reports appear in this issue of the TRANSACTIONS; the rest will be published in the November and December issues.

A brief outline of the convention proceedings is given in the following paragraphs.

MONDAY, SEPTEMBER 22.

The convention was called to order at 10 A. M. by the chairman of the Convention Committee, Mr. C. A. Littlefield. An address of welcome was made by Mr. William H. Stevenson, president of the Pittsburgh Chamber of Commerce. An appropriate response on behalf of the society was made by Mr. Norman Macbeth, vice-president.

A historic gavel and stand was presented to the society by Prof. George Hoadley on behalf of the Philadelphia Section. Inserted in the gavel, which is of rosewood, are several contributions or souvenirs, each one of which designates a stage or significant achievement in the lighting industry. The stand consists of a piece of a gas holder built in Baltimore by the first gas company in America, established in 1816, set in a case of rosewood. A detailed description of the gavel and stand will appear in another issue of the TRANSACTIONS.

The address by President Preston S. Millar surveyed the status of the present day lighting conditions. Based on an exhaustive canvass of numerous sources of information, it constitutes a comprehensive appraisal with which future estimates of progress in the science and art of illumination may be compared. The address will be published in a later issue of the TRANSACTIONS.

A report of the Committee on Organization of the International Committee on Illumination was read by Mr. George S. Barrows. The report reviewed the

movement started about two years ago for the formation of an international body to consider questions pertaining to illumination. A meeting was held July 8 for the organization of a United States National Committee and was attended by delegates from the American Gas Institute, American Institute of Electrical Engineers, American Physical Society and the Illuminating Engineering Society. Dr. E. P. Hyde, a past-president of the I. E. S., was elected president and Dr. C. H. Sharp secretary of the United States National Committee. A meeting to reorganize the International Photometric Commission was held in Berlin, August 27 to 30, 1913. Ten nations were represented by forty-four delegates. The name of the Commission was changed to the International Illumination Commission and statutes for its conduct were adopted. These provide for the formation of national committees by the national technical societies interested in lighting. The business of the Commission is to be transacted by these committees, acting through the honorary secretary of the Commission, through delegates sent to the general meetings which are to be held every three years and through standing committees. The next meeting of the Commission is to be held in Paris in 1916. A more detailed and formal report on the proceedings and status of the new Commission is to be received shortly from the United States National Committee and will be published in a later issue of the TRANSACTIONS.

The report of the Committee on Progress was next presented by Mr. F. N. Morton, chairman of the committee. The report appears in this issue.

At the afternoon session three papers were presented: "Recent Improvements in Incandescent Lamp Manufacture," by E. J. Edwards and Ward Harrison; "The Cooling Effect of Leading in Wires upon the Filaments of Tungsten Incandescent Lamps of the Street Series Type," by T. H. Amrine; "Modern Practise in Street Railway Illumination," by S. G. Hibben.

In the evening there was a reception and dance in the ball-room of the Hotel Schenley.

TUESDAY, SEPTEMBER 23.

Three papers were read during the morning session: "The Psychic Values of Light, Shade, Form and Color," by F. Park Lewis, M. D.; "The Efficiency of the Eye Under Different Systems of Illumination, and the Effect of Variations in Distribution and Intensity of Light," by C. E. Ferree of Bryn Mawr College; and "Some Theoretical Considerations of Light Production," by W. A. Darrah. In connection with the discussion of the latter paper, Mr. John W. Howell of the General Electric Company gave a talk on current developments in the manufacture of incandescent lamps. Several large high candle-power nitrogen-filled, tungsten filament lamps were exhibited. Mr. C. A. B. Halvorson, Jr., of the West Lynn Works of the General Electric Company discussed the status of the arc lamp, referring particularly to the magnetite lamp.

In the afternoon an inspection trip was conducted to the works of the Westinghouse Electric & Manufacturing Company in East Pittsburgh.

The Section Development Committee held a conference of the representatives of section boards for the discussion of section activities for the season beginning October 1.

There was also a special meeting of the Council in the afternoon. A report of this meeting appears elsewhere in this issue.

An evening session, to which the public was invited, was held in the Allegheny County Soldiers' Memorial Hall. The lighting of this building, which has been described in a paper in the TRANSACTIONS, was the subject of a talk by Mr. Henry Hornbostel, the architect of the building.

Mr. Georges Claude gave a lecture on the neon tube lamp of which he is the inventor, and showed several of the lamps in operation. The lecture is included in this issue of the TRANSACTIONS.

Two papers, "The Evolution of the Lamp" by Roscoe E. Scott and "The Quartz Mercury-vapor Lamp" by W. A. D. Evans were also presented.

WEDNESDAY, SEPTEMBER 24.

This day was designated as "Commercial Day" and was devoted to a discussion of various lighting installations involving the practical applications of scientific lighting principles. The papers discussed were: "Church Lighting" by R. B. Ely; "Experiments in the Illumination of a Sunday School Room with Gas" by E. F. Kingsbury; "Distinctive Store Lighting" by C. L. Law and A. L. Powell; "Factory Lighting" by M. H. Flexner and A. O. Dicker; "Store Lighting" by J. E. Philbrick; "Hospital Lighting" by W. S. Kilmer.

Wednesday afternoon the members of the society were guests at a baseball game between the Pittsburgh and Chicago teams of the National League.

The annual banquet was held in the evening. Prof. H. S. Hower of the Reception Committee presided and introduced the toastmaster General George H. Harries. Addresses were made by President P. S. Millar, President-elect C. O. Bond, Charles M. Bregg and John Brashear, "Pittsburgh's Grand Old Man." Music was furnished by th Westinghouse Band.

THURSDAY, SEPTEMBER 25.

At the morning session the followin papers were read: "The Lighting o Show Windows" by H. B. Wheeler "The Pentane Lamp as a Workin Standard" by E. C. Crittenden and A. H Taylor; "The Illuminating Engineerin Laboratory of the General Electri Company" by S. L. E. Rose; "Th Photo-Electric Cell in Photometry" b Prof. F. K. Richtmyer; "Some Studie in the Accuracy of Photometry" by E. J Edwards and Ward Harrison.

At noon a number of the member attended a luncheon of the Jovians i the Hotel Schenley. Statesman F. M Knapp of the latter organization presided. Short talks were given by Preston S. Millar, L. B. Marks, Norma Macbeth, C. A. Littlefield and Georg Webster. Music was furnished by th orchestra of the Western Union Telegraph Company.

The afternoon session was opened b a paper entitled "Characteristics of Enclosing Glassware" by V. R. Lansingh The session was concluded by a genera meeting of the society. The annua report of the Council to the membership was presented by Joseph D. Israel general secretary. The report will b published in a later issue of the TRANSACTIONS.

The committee appointed at the firs session of the convention to report o the presidential address then presente the following report:

Your Committee desires to commend the Re port of your President for the careful perusal o each individual member of the Society. As record of the present status of the Art of Illum ination, it should assume an important place i the archives of the Society.

The classification of the elements of lightin practise into the so-called categories, is mos useful not only in expressing present day co

ditions, but also as a means of evaluating future progress. The careful and extensive survey of lighting conditions through broadcast distribution of questions will undoubtedly yield much important information.

Your Committee trusts that the President will carry this investigation through to a conclusion and make available such instructive data as may be obtained.

A further important result may be anticipated from this survey, that it will set to thinking a large number of persons more or less interested in the subject of Illumination, thereby stimulating activity on the subject.

To the Council it is desired to recommend for consideration the President's suggestion that an effort be made to secure commercial application of the valuable information which is being continuously presented to the Society.

Your Committee believes it will be found desirable to appoint a committee to investigate the suggestion of the President, and recommend not only with regard to carrying it out but also with regard to the ways and means.

Respectfully submitted:

G. S. Barrows,
Norman Macbeth,
G. H. Stickney, (*Chairman*).

A Committee on Resolutions presented the following resolutions, which were unanimously adopted:

Whereas, The Seventh Annual Convention of the Illuminating Engineering Society is about to terminate its sessions, and

Whereas, in general interest it has fully maintained the high standard set by preceding meetings of the Society, and

Whereas, this result has only been accomplished through the indefatigable effort and cooperation of those charged with the responsibility of the preparation for and the conduct of the work. Be it Resolved:

That the thanks of the delegates be extended

To the Pittsburgh Section for their invitation to visit Pittsburgh and their generous hospitality;

To the General Convention Committee for the comprehensive plan laid out by and so ably accomplished through their unceasing efforts;

To the various Executive, Local and other Committees who, by unselfish devotion to their duties, have so largely added to the comfort and entertainment of those in attendance;

To the President of the Pittsburgh Chamber of Commerce for his cordial welcome;

To the County Commissioners for permission to use Allegheny County Memorial Hall for a session;

To the Management of the Hotel Schenley for the many courtesies extended to the delegates and guests; and

To the authors of the papers and the speakers, without whose valued efforts the success of this meeting would have been impossible; and

Be it Further Resolved, that copies of these resolutions be forwarded to the Pittsburgh Section, to the President of the Pittsburgh Chamber of Commerce, to the County Commissioners, to the Chairmen of the various Committees, to the Management of the Hotel, and that they be spread upon the minutes of the Society.

President Millar then introduced President-elect Charles O. Bond who made a brief address in response to the hearty reception which was accorded him.

Mr. L. B. Marks introduced a resolution commending the work of President Millar and his administration, which was adopted unanimously. The convention was then adjourned.

In the evening there was a theater party at the Grand Opera House.

During the convention special entertainment was provided for the ladies. Monday afternoon there was a card party at the Pittsburgh Athletic Club. Tuesday a luncheon was served at the factory of the H. J. Heinz Company; there was also an automobile trip through the city parks. Thursday afternoon visits were made to the Carnegie Institute and the Margaret Morrison School.

In the way of sport for the men there were several games of golf, and a tennis game for a silver trophy which was won by J. L. Wiltse.

Council Notes.

During the seventh annual convention in Pittsburgh, a special meeting of the Council was held September 23, 1913, in the Hotel Schenley. Those present were: Preston S. Millar, president; George S. Barrows, C. O. Bond, Joseph D. Israel, general secretary; V. R. Lan-

singh, Norman Macbeth, L. B. Marks, treasurer; and W. J. Serrill.

The Executive Committee reported that it had transacted the following business since the last regular meeting of the Council in June. The report was adopted.

Authorized the payment of vouchers Nos. 1359 to 1390 inclusive, amounting to $3600.48; and vouchers Nos. 1391 to 1420 inclusive, amounting to $1187.56.

An appropriation of $70 covering the cost of programs, postage, etc., issued in conjunction with the joint meeting of the Illuminating Engineering Society and the School Hygiene Congress in Buffalo (August 25-30, 1913), was granted.

Elected twenty applicants to membership. The names of these new members are given on another page of this issue of the TRANSACTIONS.

Approved the appointment of the following local representatives:

ABBOTT, A. L.
Manager, Northwestern Electrical Equipment Company, St. Paul, Minn.

COLLIER, WILLIAM RAWSON.
Georgia Railway & Light Company, Atlanta, Ga.

HOAR, F. EMERSON.
Railroad Commission of the State of California, 833 Market Street, San Francisco, Cal.

MANAHAN, R. H.
City Electrician, Los Angeles, Cal.

OSBORN, FRED. A.
University of Washington, Seattle, Wash.

WILLIAMSON, G. E.
Denver Gas & Electric Light Company, Denver, Colo.

Approved appointment of two representatives (Dr. E. P. Hyde and Mr. L. B. Marks) from the Illuminating Engineering Society to a meeting of representatives of several societies for the purpose of organizing a United States National Committee. The organization of this committee is in line with a movement started about two years ago for the formation of an international body to consider questions pertaining to illumination.

A draft of the annual report of the general secretary was read. This report with a few changes was made the report of the Council to the membership of the society.

An appropriation of $1,005 was granted to cover expenditures to be made by the Convention Committee in connection with the Seventh Annual Convention.

An appropriation of $35 was granted to cover the cost of issuing notices announcing a joint meeting of the Illuminating Engineering Society and the American Gas Institute during the convention of the latter organization in Richmond, Va., in October.

The Finance Committee was directed to engage a public accountant to audit the accounts of the society for the period January 1 to September 30, 1913, at a cost not to exceed $50.

The following resolution was adopted.

WHEREAS, at this special meeting of the Council of the Illuminating Engineering Society, held in the Hotel Schenley, Pittsburgh, Pa., September 23, 1913, during the period of the Seventh Annual Convention of the Society, it is deemed fitting and desirable that the Council recognize the distinguished services of the several committees which have done so much to help the society's work in support of the 1913 administration; therefore be it

Resolved, that the secretary be instructed to forward to the chairman of each standing and temporary committee, as well as to the chairmen of the convention and sub-committees a copy of this resolution, as an appreciation by the Council of the committee work which was so marked a feature of the activities of the society during the year 1913, and as a recognition of the efficiency with which the several committees performed their various duties; be it further

Resolved, that the Council place on record in this manner a renewal of its

expression of appreciation of the fidelity and efficiency of the Assistant Secretary, Mr. Joseph Langan, and his office assistants.

It was voted to recommend to the next Council the question of considering ways and means of establishing the responsibility of the society for all statements made in papers presented by members of the society at joint meetings with other societies.

Prof. George D. Shepardson of the University of Minnesota, Minneapolis, Minn., was appointed a local representative of the society.

Mr. V. R. Lansingh, chairman of the Committee on Sustaining Membership, reported on the status of the sustaining membership of the society.

It was voted to refer to the next Council the question of supplying reprints and copies of papers to authors.

Vouchers Nos. 1421 to 1442 inclusive, amounting to $691.20, were authorized paid, subject to subsequent approval by the Finance Committee.

The first regular Council meeting of the administration 1913-1914 was held in the general offices of the society, 29 West 39th Street, New York, October 10, 1913. In attendance were: C. O. Bond, president; Ward Harrison, J. D. Israel, general secretary; V. R. Lansingh, C. A. Littlefield, L. B. Marks, treasurer; Preston S. Millar, W. J. Serrill, G. H. Stickney.

The meeting was called to order by President Bond at 10:40 a. m.

The minutes of a special meeting of the Council, which was held September 23 in the Hotel Schenley, Pittsburgh, Pa., during the Annual Convention, were adopted.

Payment of vouchers 1443 to 1458 inclusive, amounting to $992.10, was authorized.

Ten applicants were elected members. Their names appear elsewhere in this issue.

Eleven resignations from membership were accepted.

Two applicants for sustaining membership were elected.

It was voted to hold the regular meetings of the Council during the present administration on the Friday following the second Thursday of each month, at 10:30 a. m.

The following suggestions from the preceding Council were referred to the Finance Committee for recommendations:

(1) Set aside at the beginning of each year for immediate investment in such securities as may be recommended by the Finance Committee, a sum of money equal to 3 per cent. of the preceding year's total revenue. To provide for future contingencies of an extreme character, some such provision seems warranted.

(2) The moneys of the Society might be deposited in a bank or trust company which will allow interest on monthly or periodical balances. The revenue from such a source might easily exceed $100 annually.

The following suggestion from the preceding Council was discussed and referred to the Committee on Progress for recommendations:

With a view to making the TRANSACTIONS more valuable as a reference publication, a list of current books and articles pertaining to illuminating engineering might be published each month in the TRANSACTIONS. Were a brief statement of the contents to accompany the titles of these publications, this contribution would be of so much greater value.

President Bond was directed to appoint a special committee to reconsider the policy of the society in regard to supplying authors with copies of their papers which are published in the TRANSACTIONS. The present practise is to give each author 50 of the advance copies of his paper. When a paper is not published in advance form, the author does not receive any copies.

President Bond appointed the following committee: G. H. Stickney, Chairman; Dr. C. H. Sharp, Dr. Herbert E. Ives. It was understood that the committee would submit recommendations at the November meeting of the Council.

The question of establishing the responsibility of the society for statements made in papers presented by members of the society at joint meetings with other societies, and before meetings of the Illuminating Engineering Society, was referred to the Papers Committee for recommendations, to be submitted at the November meeting of the Council. It was suggested that a note of some sort might be placed upon each paper, stating that the society does not necessarily identify itself with the views or opinions expressed in its papers.

An invitation from the American Museum of Safety to the society, to join in a session to be devoted to illumination, during an exhibition of the former organization in New York, was accepted. It was understood that the Papers Committee and the Committee on Reciprocal Relations conjointly would designate lecturers or authors to appear at the session of the American Museum of Safety, on the evening of December 18 in the Grand Central Palace, New York City.

In connection with the latter meeting, $25 was appropriated for literature to be issued in conjunction with this session and a lighting exhibit which is to be installed in the Museum of Safety by a committee of the society. It was understood that the exhibit would also be displayed in the Grand Central Palace during the Museum of Safety Exhibition. This exhibit is to become part of the permanent equipment of the Museum of Safety.

Mr. G. H. Stickney, chairman of the committee having charge of the installation of a lighting exhibit in the American Museum of Safety, reported briefly on the work of his committee. He stated that the expense of construction and installation of the exhibit would be borne by several lighting and manufacturing companies.

It was voted to donate to the School Hygiene Congress a set of electros of the illustrations in the illumination primer "Light: Its Use and Misuse" and a copy of the primer, with the understanding that it would be incorporated verbatim and in its entirety in the published proceedings of the Congress which was held in Buffalo in August, 1913. The electrotypes are to be forwarded to Dr. Thomas A. Storey of the College of the City of New York, who is secretary of the Congress.

Mr. Ward Harrison of the National Electric Lamp Association of Cleveland, was appointed a local representative of the society in the city of Cleveland, Ohio.

The following local representatives were reappointed for the present administration:

ABBOTT, A. L.
Manager, Northwestern Electrical Equipment Company, St. Paul, Minn.

COLLIER, WILLIAM RAWSON.
Georgia Railway & Light Company, Atlanta, Ga.

HOAR, F. EMERSON.
Railroad Commission of the State of California, 833 Market Street, San Francisco, Cal.

MANAHAN, R. H.
City Electrician, Los Angeles, Cal.

OSBORN, FRED. A.
University of Washington, Seattle, Wash.

SHEPARDSON, G. D.
Professor of Electrical Engineering, University of Minnesota, Minneapolis, Minn.

Williamson, G. E.
Denver Gas & Electric Light Company, Denver, Colo.

The following committee chairmen were appointed:

Progress:
F. E. Cady, National Electric Lamp Association, Cleveland, Ohio.

Glare:
M. Luckiesh, National Electric Lamp Association, Cleveland, Ohio.

Popular Lectures:
G. H. Stickney, General Electric Company, Harrison, N. J.

Sustaining Membership:
V. R. Lansingh, 6523 Euclid Avenue, Cleveland, Ohio.

Advertising:
J. Robert Crouse, The National Electric Lamp Association, Nela Park, Cleveland, Ohio.

Lighting Legislation:
L. B. Marks, 103 Park Avenue. New York City.

Section Development:
Joseph D. Israel, 1000 Chestnut Street, Philadelphia, Pa.

Papers:
George H. Stickney, General Electric Company, Harrison, N. J.

It was resolved that the Council at this time renew its expression of appreciation of the excellent work done by the Primer Committee in the preparation of the illumination primer "Light: Its Use and Misuse"—the best piece of constructive work the society has ever accomplished.

The following Council Executive Committee was appointed:

Charles O. Bond (*ex-Officio*), Chairman,
3101 Passyunk Avenue, Philadelphia, Pa.

Joseph D. Israel (*ex-Officio*),
1000 Chestnut Street, Philadelphia, Pa.

C. A. Littlefield,
55 Duane Street, New York City.

L. B. Marks (*ex-Officio*),
103 Park Avenue, New York City.

Preston S. Millar,
80th Street and East End Avenue, New York City.

Section Notes.

CHICAGO SECTION.

A meeting of the Board of Managers was held in the Grand Pacific Hotel, October 15. Those present were: Dr. M. G. Lloyd, chairman; J. R. Cravath, vice-president; J. B. Jackson, secretary; J. W. Pfeifer, C. C. Schiller, and H. B. Wheeler.

The getting of suitable papers on car lighting for the November meeting was discussed. Dr. Lloyd and Mr. Jackson were delegated to complete arrangements for the meeting.

It was announced that Mr. W. A. Durgin, assistant chief testing engineer of the Commonwealth Edison Company, would give a series of talks on the basic principles of illumination before the section meetings during the present season.

A proposed joint meeting with the Railway Signal Association was discussed. The making of definite arrangements for this meeting was withheld pending further correspondence with the association.

Committee appointments will be announced later.

A meeting of the Chicago Section was held in the auditorium of the Western Society of Engineers, Monadnock Block, October 15. Vice-president J. R. Cravath reviewed the proceedings of the Pittsburgh convention. Two papers:

"Factory Lighting" by Messrs. M. H. Flexner and A. O. Dicker and "The Lighting of Show Windows" by H. B. Wheeler were presented. Demonstrations and exhibits of factory lighting fixtures, show window reflectors and the new nitrogen lamps were provided. A report from the previous board on the work of the past year was read by Secretary J. B. Jackson. Dr. M. G. Lloyd presented a tentative outline of the meetings, papers, etc., for the present year. Twenty-five members and five guests were present.

NEW ENGLAND SECTION.

The Board of Managers of the New England Section expect to announce shortly a tentative program of papers and meetings for the present season.

Mr. C. M. Cole, 156 Pearl Street, Boston, Mass., has been appointed secretary of the section.

NEW YORK SECTION.

The Board of Managers held two meetings in the general offices of the society, 29 West 39th Street, New York, September 2 and 29 respectively. A brief of the business transacted at these meetings is given below:

It was decided that, whenever possible during the present year, joint meetings should be held with other societies. Meetings with the following organizations were suggested: National Electric Light Association, Sage Foundation for the Prevention of Blindness, American Society of Mechanical Engineers, New York Electrical Society, National Commercial Gas Association and the Municipal Art Society. The secretary was instructed to prepare a budget for the coming season. An effort will be made to have issued some time in October or early in November a printed tentative program, listing papers, meetings, etc., for the entire season. Mr. A. S. Ives was appointed a manager to succeed C. R. Clifford, resigned. It was voted to hold, as far as possible, an informal dinner, immediately preceding each section meeting, at Keene's Chop House, 70 West 36th Street, New York, on the evenings of the section meetings. Twelve applications for membership were approved by the Board of Managers and transmitted to the secretary of the society.

The following committee chairmen have been appointed: Papers, H. V. Allen; Membership, H. B. McLean; Dinner, S. W. Van Rensselaer; Attendance, N. D. MacDonald; Exhibition, W. H. Spencer; Reception, C. L. Law.

A meeting of the New York Section was held in the United Engineering Societies' Building, 29 West 39th Street, New York, October 9. Mr. Norman Macbeth reviewed the proceedings of the seventh annual convention of the society in Pittsburgh, in September.

A paper entitled "Distinctive Store Lighting," which had been presented at the convention, was presented by Messrs. C. L. Law and A. L. Powell. The latter paper was accompanied by a series of lantern slides and autochrome color plates demonstrating the advantages of using color slides in photographic work. Preceding the meeting there was an informal dinner at Keene's Chop House, 70 West 36th Street.

PHILADELPHIA SECTION.

The Board of Managers of the Philadelphia Section held two meetings, one July 18 and another September 5, 1913.

The following committee chairmen have been appointed: Papers, H. A. Hornor; Exhibition, H. Calvert; Membership, Samuel Snyder; Publicity, H.

H. Ganser; Dinner, F. C. Dickey; Attendance, R. B. Ely.

A meeting of the Philadelphia Section was held in the Engineers' Club, 1317 Spruce Street, Philadelphia, October 17. A paper entitled "A Simple Unit Method of Measuring Intrinsic Actinicity of Flames and Surfaces for the Practise of Photography" by Mr. F. M. Steadman was presented by Prof. A. W. Goodspeed, of the University of Pennsylvania. Vice-President W. J. Serrill reviewed the proceedings of the seventh annual convention of the society in Pittsburgh, September, 1913. During the meeting there was an exhibition of photographic lamps and lenses. About 60 members were present. An informal dinner at the Engineers' Club preceded the meeting.

The following program of meetings and papers has been printed and issued to the members of the section.

FRIDAY, OCTOBER 17.

Joint Meeting with Photographic Society of Philadelphia.

"A Simple Unit Method for Measuring the Intrinsic Actinicity of Flames and Surfaces for the Practise of Photography." By Mr. F. M. Steadman.

Presented by Prof. A. W. Goodspeed.

Address by Prof. Geo. A. Hoadley.

Report of Pittsburgh Convention.
By Mr. William J. Serrill.

Exhibition of Photographic Lenses and Shutters.

THURSDAY, NOVEMBER 20.

Joint Meeting with Ophthalmologists of Philadelphia at the College of Physicians and Surgeons.

"Some Effects of Artificial Light upon the Eye."
By Dr. Edward A. Shumway.

"The Effect of Mercury Arc Lamps upon the Eyes."
By Dr. Geo. S. Crampton.

"The Lighting of a Private Library."
By Prof. Arthur J. Rowland.

MONDAY, DECEMBER 8.

Joint Meeting with Philadelphia Section A. I. E. E.

"Brightness Measurements versus Illumination Measurements."
By Dr. Herbert E. Ives.

"Railway Car Lighting."
By Mr. Geo. H. Hulse.

"The Mercury Quartz Tube Lamp."
By Mr. Buckman.

FRIDAY, JANUARY 6.

"Deficiencies of the Method of Flicker for the Photometry of Lights of Different Colors."
By Prof. C. E. Ferree.

SATURDAY, FEBRUARY 7.

Meeting under the Auspices of Drexel Institute.

"Light and How to Use It."
By Mr. C. O. Bond, President of I. E. S.

WEDNESDAY, FEBRUARY 18.

Joint Meeting with Franklin Institute.

"Artificial Daylight."
By Dr. Herbert E. Ives.

FRIDAY, MARCH 20.

"Lighting and Signalling Systems of Subways."
By Mr. F. D. Bartlett.

"The Sun—The Master Lamp."
By Prof. James Barnes.

THURSDAY, APRIL 9.

Joint Meeting with Franklin Institute.

"Recent Developments in the Art of Illumination."
By Mr. Preston S. Millar.

FRIDAY, APRIL 17.

"The Structure of the Normal Eye and its Ability to Protect Itself Against Ordinary Light."

By Dr. Wendell Reber.

"Glassware for Illumination and Other Purposes."

By Mr. James Gillinder.

FRIDAY, MAY 15.

Mass Meeting of all the Engineering Societies of Philadelphia and Vicinity.

Special Program to be arranged and to include an address on

"The Relation of Engineers to the Progress of Civilization."

By Dr. Chas. Proteus Steinmetz.

PITTSBURGH SECTION.

The Board of Managers of the Pittsbugh Section has announced the following tentative program of meetings and papers for the present season:

October—"Technical Elements of Vision" by Dr. H. H. Turner.

November—"Technical Discussion of the Elements of Lighting" by Prof. Hower and others.

December—A joint meeting with the Pittsburgh Section of the American Institute of Electrical Engineers. A Central Station paper will be presented by H. N. Muller of the Duquesne Light Company.

January—A paper to be selected by the members from Cleveland. The subject will be announced later.

February—"Railroad Yard Lighting" by A. C. Cotton and A Kirschberg of the Pennsylvania Railroad Company.

March—A gas lighting subject; the speaker to be announced later.

April—"Developments of Flame Carbon Arc Lamps" by C. E. Stephens.

May—"Store Lighting"; speaker to be announced later.

June—Open.

The following committee chairmen have been appointed: Papers, C. E. Stephens; Exhibition, S. G. Hibben; Membership, C. H. Mohr; Publicity, M. C. Turpin; Dinner, R. H. Skinner; Reception, V. R. Lansingh; Education, W. A. Darrah.

New Members.

The following applicants were elected members of the society September 5, 1913:

AIRSTON, ALEXANDER.
Head of Factory Lighting Department, Westinghouse Electric & Mfg. Company, East Pittsburgh, Pa.

BLUMENAUER, C. H.
President and Treasurer, Jefferson Glass Company, Follansbee, W. Va.

BOWEN, DUDLEY A.
Salesman, Westinghouse Electric & Mfg. Company, 165 Broadway, New York, N. Y.

BRAND, WALTER C.
Illuminating Engineer, Macbeth-Evans Glass Company, Wabash Building, Pittsburgh, Pa.

BULLARD, JOHN E.
Manager New Business Department, Public Service Corporation of L. I., Port Washington, N. Y.

CADBY, J. N.
Chief Inspector of Electric Service, R. R. Commission of Wisconsin, Madison, Wis.

DAMRON, C. E.
Assistant in Commercial Engineering Department, General Electric Company, Harrison, N. J.

HAKE, HARRY G.
Assistant Professor of Electrical Engineering, Washington University, St. Louis, Mo.

HARRISON, HAYDN T.
Electrical and Illuminating Engineer, 11 Victoria Street, London, S. W., England.

LANGWORTHY, E. L.
Eastern Manager, The Adams & Westlake Company, 2218 Ontario Street, Philadelphia, Pa.

McNARY, S. J.
Vice-President and Illuminating Engineer, The E. G. Jones Electric Company, 141 East 4th Street, Cincinnati, Ohio.

PASCOE, C. C.
Manager of Lamp Sales and Illumination Department, General Electric Company, 185 Paseo Colon, Buenos Aires, Argentine Republic.

RILEY, F. M. H.
Lighting Specialist, Kansas City Electric Light Company, Grand Avenue, Kansas City, Mo.

STANNARD, CLARE N.
Secretary, Denver Gas & Electric Light Company, Denver, Colo.

SWALLOW, JOSEPH G.
Chief of Installation and Inspection, United Electric Light & Power Company, 1170 Broadway, New York, N. Y.

TROTTER, A. P.
Electrical Engineer and Advisor, Board of Trade, Whitehall, London, S. W., England.

VOYER, LEONARD E.
Assistant in Illuminating Engineering Laboratory, General Electric Company, Harrison, N. J.

WALTERS, G. L.
Sales Manager, The Adams & Westlake Company, 319 West Ontario Street, Chicago, Ill.

WATKINS, FREDERICK A.
District Sales Manager, Pittsburgh Reflector & Illuminating Company, 565 West Washington Street, Chicago, Ill.

WILLIAMSON, G. E.
Denver Gas & Electric Light Company, Denver, Colo.

The following applicants were elected members October 10, 1913:

ATMORE, A. L.
Engineering Department, Philadelphia Electric Company, 1000 Chestnut Street, Philadelphia, Pa.

BARNES, JAMES.
Professor of Physics, Bryn Mawr College, Bryn Mawr, Pa.

FEDERER, THEO. P.
Incandescent Lamp Salesman, General Electric Company, 30 Church Street, New York, N. Y.

FORTUNE, F. R.
Lighting Specialties Company, 650 Century Building, Pittsburgh, Pa.

GRAY, HENRY J. W.
Philadelphia Electric Company, 1000 Chestnut Street, Philadelphia, Pa.

LOFQUIST, HARRY S.
Engineering Department, National Lamp Works of General Electric Company, Nela Park, Cleveland, O.

McQUISTON, J. C.
Advertising Manager, Westinghouse Electric & Mfg. Company, East Pittsburgh, Pa.

MOON, T. ELMER.
Illuminating Engineer, James E. Hamilton Engineering Co., 1625 Real Estate Trust Building, Philadelphia, Pa.

STRAIT, E. N.
Public Utility Expert, Railroad Commission of Wisconsin, Madison, Wis.

TURPIN, M. C.
Westinghouse Electric & Mfg. Company, East Pittsburgh, Pa.

Sustaining Members.

The following additional applicants have been elected sustaining members of the society:

ALEXALITE COMPANY.
432 East 23rd Street, New York, N.Y.

BOARD OF WATER COMMISSIONERS.
City Hall, London, Ontario, Canada.

COOPER HEWITT ELECTRIC COMPANY.
Eighth and Grand Streets, Hoboken, N. J.

EDISON ELECTRIC ILLUMINATING CO. OF BROCKTON.
42 Main Street, Brockton, Mass.

H. W. JOHNS-MANVILLE COMPANY.
Madison Avenue and 41st Street, New York.

LITTLE ROCK RAILWAY & ELECTRIC COMPANY.
115 West 4th Street, Little Rock, Ark.

PITTSBURGH LAMP, BRASS & GLASS CO.
Pittsburgh, Pa.

THE LEEDS & NORTHRUP COMPANY.
4901 Stenton Avenue, Philadelphia, Pa.

Local Representatives.

To extend the influence and work of the society into cities and territories in which there are not sections of the society the Council has recently appointed eight local representatives. The names of the representatives are listed on a page in the front part of this issue. These representatives will communicate to the general secretary from time to time information concerning local developments in which the society is concerned. They will also endeavor to promote occasional meetings under the joint auspices of the I. E. S. and local organizations.

TRANSACTIONS

OF THE

Illuminating Engineering Society

OCTOBER, 1913

PART II

Papers, Discussions and Reports

[OCTOBER, 1913]

CONTENTS -- PART II

REPORT OF THE COMMITTEE ON PROGRESS.*

To the Illuminating Engineering Society:

During the past year the science of illumination has probably made greater progress than at any other similar period of its history. While few radical changes or developments have been made in connection with light sources, improvements have been made in mechanical construction of present systems, resulting in increased efficiency, and illumination has become the subject of study by physicists, oculists, architects, legislative bodies and others as never before.

INCANDESCENT ELECTRIC LAMPS.

In connection with light sources the development of the tungsten lamp stands out most prominently. This, in high candle-powers, is a serious competitor of the arc lamp both for indoor and outdoor lighting, and has largely superceded the carbon filament lamp, as shown by the following table taken from a recently published article, and giving the relative number of lamps sold.[1]

Type	Per cent. 1907	Per cent. 1908	Per cent. 1909	Per cent. 1910	Per cent. 1911	Per cent. 1912
Carbon...	93.27	84.12	68.98	63.08	52.90	25.47
Gem	5.88	8.58	15.07	14.88	19.00	33.59
Tantalum	0.75	1.78	2.12	3.57	2.74	1.00
Tungsten.	0.10	5.52	13.83	18.47	25.30	39.94
Total	100.00	100.00	100.00	100.00	99.94	100.00

It is extremely probable that more recent figures will show that the tungsten lamp, aided by greatly reduced price, its high efficiency and the fact that electric companies are beginning to make free renewals of tungsten lamps as they did of the carbon filament, is destined to make the carbon filament lamp a vanishing quantity. In this connection it is interesting to note that the United States government has issued an order through the office of the supervising architect of the Treasury Department that carbon and metallized carbon-filament lamps are not to be used

* A report read at the seventh annual convention of the Illuminating Engineering Society, Pittsburgh, Pa., September 22-26, 1913.

[1] *Lighting Journal*, July, 1913.

in any of the government buildings, and any such lamps in use at the time of the receipt of the order must be removed and 25-watt tungsten lamps substituted.[2]

There has been marked improvement in the life of some of the higher wattage 100-volt types and in compensator and train lighting lamps. In the 60, 100 and 150-watt, 100-volt lamps improvements in life have taken place similar to those made last year in the cases of the 250, 400 and 500-watt lamps. This improvement in quality is on the order of 50 per cent. in life and has made possible substantial improvements in efficiency. The use of chemicals—the so-called "vacuum getter," in the bulbs of these lamps for reducing the blackening of globes has largely brought about these improvements.[3, 4] At present the commercial efficiencies of these types are around 1.17 w. p. c. while the higher wattage types are put out at about 1 w. p. c.[3, 4]

To meet a demand for a 60-watt small base lamp for use in residence lighting and to provide a 40-watt lamp that will in all cases be interchangeable with the 25-watt lamps these two types are now made in smaller bulbs. The 60-watt lamp is now made in the same bulb as was standard for 40-watt lamps and the 40-watt lamp in the bulb which is now standard for 25 watts. This change has been made without impairing the life or efficiency of the lamps.[3]

Improvements in the tungsten wire-drawing process have made it possible to manufacture wire of almost exactly the desired size and so render it possible for manufacturers to make lamps of so nearly the desired voltage and efficiency that the function of photometry in the lamp factory is now principally to guard against errors in manufacture. This improvement has been adopted by most of the manufacturers in this country for all lamps intended for series burning service and has been productive of greatly improved results in all cases.[3]

A 10-watt, 100 to 130-volt lamp and a 5-watt, 50 to 60-volt lamp have been developed. These are important additions to the line of sign lamps in that they furnish a low wattage lamp

[2] *Electrical World*, March 15, 1913.

[3] *Electrical Journal*, June, 1913.

[4] *Electrical Journal*, January, 1913.

that does not require the operation of more than two lamps in series upon 100 or 200-volt circuits.

Miniature lamps of the candelabra and decorative types with tungsten filaments have been developed for 110-volt circuits. These have the filaments wound to form a helical coil of small diameter and this helix is then mounted on the supports in the same manner as an ordinary filament. The mandrel around which the filament is formed is so small that the helical construction of the filament can scarcely be recognized with the naked eye. This style of construction renders possible the use of fewer supports and smaller bulbs than ordinary tungsten lamp construction would allow.[3]

During the past year the use of concentrated filament tungsten lamps has enormously increased. At the present time a very large proportion of the automobiles now being sold in this country are equipped with these lamps. Concentrated filament lamps are also being used for stereopticon work, for trolley car headlights and for theatre stage lighting in place of arc lamps and Nernst lamps. With the style of construction now used excellent concentration is obtained; the filament for a 100-watt, 115-volt lamp occupies a space only 7/16 inch (11.113 mm.) in diameter and 7/16 inch long.

A new filament consisting of an alloy of tungsten has also been brought out. It is claimed that this not only possesses the strength and efficiency of drawn tungsten, but that it will withstand crystallization for a longer period.[5]

An investigation has been made upon the heating of screw thread lamp sockets. This was found to be almost entirely due to the heat dissipated by the lamp or radiator and has little to do with the energy lost in contacts. Bayonet holders are satisfactory up to 250 watts, while screw sockets can transmit energy up to 1,000 watts with satisfaction.[6]

Possibly the most startling development in the tungsten lamp is the announcement of one giving an efficiency of 0.5 watt per candle. A specially shaped tungsten filament is used in a bulb containing an inert gas, as nitrogen, at a pressure of about one

[5] *Electrical World*, December 7, 1912.

[6] *Electrician*, June 27, 1913.

atmosphere. The types to be developed first are adapted to high current consumption, say 6 amperes and over.[7]

A tungsten lamp has recently been brought out which gives a color very closely resembling that of daylight. It is not, however, an exact equivalent, and is, therefore, not suited to color matching. The energy consumption of this lamp is about 1.4 watts per candle, and it has a candle-power of from 70 to 75.[8,9]

A method of testing for spots in incandescent lamp filaments has been developed in which the body of a filament is made to disappear against a luminous background until the light or dark spot shows by contrast.[10]

Experiments were made to determine the variation in candle-power produced by frosting. The distribution curves were found to be very much the same before and after frosting, and half-frosting resulted in a reduction of from 10 to 20 per cent. in the candle-power. One fact brought out in these experiments was of practical use in permitting a close estimate to be made of the efficiency of a half frosted bulb. It was found that the curves for the distribution of light of each lamp, clear and half frosted, intersected at an angle very close to 66° in each case, and the candle-power at this angle is in each case very nearly 45 per cent. of the horizontal candle-power of the clear lamp. Thus the horizontal candle-power of the clear bulb may be obtained by multiplying that obtained with the half frosted bulb at 66° by 2.22.[11]

A focusing tungsten lamp with a spherical bulb silvered near the socket has been introduced within the past year. This lamp, which is rated at 32 candle-power has an efficiency of 1 watt per candle. In another lamp there is a specially shaped reflector in close proximity to the filament. The leading-in wire enters at the apex of the reflector and leaves at its circumference.[12]

A system has been developed in which 14-volt lamps are used with a special transformer for each lamp or for each group of lamps. Each transformer is connected in parallel to the line,

[7] *Electrical World*, July 19, 1913.
[8] *Zeit. für Beleucht.*, April 30, 1913.
[9] *Elek. Anzeig.*, April 24, 1913.
[10] *Electrical World*, May 3, 1913.
[11] *Electrician*, April 25, 1913.
[12] *Elek. Anzeig.*, April 24, 1913.

and when it is disconnected the primary circuit is broken so that there are no no-load losses. These lamps are cheaper than the standard 110-volt lamps, in addition to which advantage are the long life and the possibility of using low candle-power. The lamps are thought to be especially suitable for agricultural districts.[13]

In order to avoid the excessive glare inherent in filament lamps, a patent has been taken out according to which the outer surface of the lamp bulb is made in a series of fine substantially parallel grooves constituting a system of prisms. The grooves may be arranged in various ways.[14]

ELECTRIC ARC LAMPS.

The open and enclosed series and multiple arc lamps are fast disappearing, their places being taken by the magnetite and the flame arc lamps. There seems to be during the past year, as far as arc lamps are concerned, a strong tendency towards the use of larger units and the cutting down of the intrinsic brilliancy of the arc even at a sacrifice of efficiency.

The flame arc lamp is of special value in lighting large areas, and is particularly adapted to smoky and dusty places, such as foundries, blacksmith shops, and railroad train sheds. In fact one of the largest railroads in the country spent months in trying out various systems of lighting for the train shed of one of their large stations, and, after experimenting with various systems of lighting finally decided to use the flame arc lamp exclusively, adopting it also for the yard.

This lamp has been improved so that the fumes thrown off by the arc are condensed and so are prevented from forming a deposit on the globe and from escaping into the air. The lamp is also economical as far as maintenance is concerned, as one set of carbons will burn from 100 to 120 hours without attention.

A rather novel device is an arrangement for converting any enclosed arc lamp, alternating or direct current, series or multiple, and regardless of voltage, into a flame arc lamp.[15] Many minor improvements have been made in construction of the arc

[13] *Electrical World*, December 28, 1912.

[14] *Electrical World*, September 14, 1912.

[15] *Electrical World*, March 1, 1913.

lamp such as making the clutch work on the electrode indirectly, thereby keeping it independent of the size of the electrode, improving the feeding arrangement, etc. The lamps are now made to give any desired range of color and to work under any ordinary condition even, as in one lamp recently introduced, on a 25 cycle circuit, and have reached an efficiency of 0.25 watt or better per candle with possibilities of further improvement.

One of the most interesting applications of the long-hour series alternating current flame carbon arc lamp is to low frequency circuits of 25 cycles. With the unimpregnated carbon lamp, there is a flicker at each reversal of polarity which, at this frequency, is very marked. In the flame arc lamp, the light is obtained from the arc screen and is, therefore, independent of polarity.[16]

A discussion was reported about the end of last year in which were reviewed the results produced upon the stability of the electric arc by wind currents, magnetic fields, movements and presence of solid obstruction, etc.[17] In an investigation made in regard to the evaporation temperature of the arc lamp it was found that the temperature is independent of the current, but varies with atmospheric pressure, proving that the atmosphere of the crater is at the boiling temperature of carbon. A peculiar phenomenon noticed was that the positive crater seems to begin to boil at pressures below atmospheric.[18]

VACUUM TUBE LAMPS.

One of the more recent developments of the mercury vapor lamp is a combination with the tungsten, an apparent white light being thereby produced. The unit is very compact and is furnished with a novel starting device. The consumption of this lamp is claimed to be 0.73 watt per mean hemispherical candlepower.[19] Another recent form of the mercury vapor lamp is one with a specially designed quartz tube and designed particularly for street lighting. This lamp is started by means of a heated spiral which vaporizes a small portion of the mercury; this is automatically cut out of circuit when the lamp is in operation,

[16] *Electrical World*, July 26, 1913.
[17] *Electrical Journal*, December, 1912.
[18] *Jnl. für Gasbel.*, July 12, 1913.
[19] *Illuminating Engineer* (London), October, 1912.

and renders tipping unnecessary. The lamp is recommended for the varying voltages met with on traction circuits and is said to consume about 0.4 watt per candle.[20, 21]

Another development has been the use of tungsten instead of platinum wires for sealing in of the electrode wires and the employment as a sealing material of a special high temperature glass, having nearly the same coefficient of expansion as the tungsten. Graded glass is inserted between the sealing glass and the quartz chamber walls in order to effect a suitably graded transition from the quartz to the sealing material.[22]

A new method has been devised, applicable to any lamp depending upon a vacuum, of sealing the conductors through the glass, and by which perfect seals may be obtained between easily oxidizable metals and glass of low fusing point. After inserting the conductor through the aperture in the glass, the latter is strongly heated by means of a blow pipe flame until perfect cohesion has been obtained between the glass and the metal. The seal is then taken out of the flame, and when it reaches a dull red, the leading-in wire and the glass surrounding it are cooled by several immersions in a special bath, say of sperm or other oil, wax or fat.[23]

The value of the ultra-violet rays of the quartz tube mercury vapor lamp is becoming recognized. The lamp is now used for sterilizing and the destruction of bacteria. This effect, however, decreases in time, due partly to the formation of an obscuring deposit.[24]

Announcement has also been made of a vapor lamp giving a white light. In this the tube is filled with the vapor of cadmium with from 3 to 10 per cent. of mercury. At its most economical point the specific consumption is 0.16 watt per candle.[25]

A new source of light for photo-electric work and said to have an effect 250 times as great as the mercury lamp has been introduced. This is a vacuum discharge tube containing hydrogen at low pressure.[26]

[20] *Electrotech. Zeitschr.*, March 20, 1913.
[21] *Elek. Anz.*, February 13, 1913.
[22] *Electrical World*, May 10, 1913.
[23] *Electrician*, July 4, 1913.
[24] Soc. Int. Elect, *Bull.* 2, Ser. 3, June, 1912.
[25] *Electrotech. Zeitschr.*, September 5, 1912.
[26] *Physical Review*, April, 1913.

Various investigations have been made upon the characteristics of neon lamps. It was found that when the tube was placed in an alternating current 4,000-volt circuit with a transformer and condenser, 0.72 amperes usefully traversed the tube. Introduction into the circuit of more neon tubes, instead of decreasing the current, apparently increased it up to four tubes, after which the current diminished. The phenomenon was not explained, but it was evidently not due to resonance.[27]

Disappearance of various gases by passing a discharge for some time through vacuum tubes was the subject of another investigation and was found to be due to definite chemical action rather than to physical absorption.[28]

Investigation made also of the cause of the short life of neon tube lamps showed that it was due to absorption of neon by the electrodes, and that if the current density at the electrodes was small, the life of the lamps would be greatly increased. By employing very large electrodes, therefore, tubes showed no deterioration in 2,000 hours' use.[29, 30]

GAS LAMPS AND APPURTENANCES.

A large number of new types of gas lighting units have made their appearance in both hemispheres. Some of them have been designed with a view to more universal adaptability, such as a burner with a curved bunsen which may be turned either up or down and is therefore, applicable to either upright or inverted burners;[31] some with a view to ease of maintenance, such as one in which the main feature is the possibility of lifting from the fixture, without the use of pliers;[32] and some with a view to increased efficiency, such as one in which the mixture of gas and air issue at high velocity;[33] resulting in an efficiency claimed to be double that of the standard type; also another lamp with an upright bunsen and an inverted mantle.[34] Low-pressure high-efficiency lamps, particularly for out-door use and giving 1,500

[27] *Le Genie Civil*, December 14, 1912.
[28] *Electrician*, November 15, 1912.
[29] *Electrician*, May 30, 1913.
[30] *Comptes rendus*, April 28, 1913.
[31] *Journal of Gas Lighting*, October 1, 1912.
[32] *Journal of Gas Lighting*, September 24, 1912.
[33] *Le Genie Civil*, November 23, 1912.
[34] *Journal of Gas Lighting*, September 14, 1912.

candle-power and with an efficiency of nearly 40 candles per foot have been introduced abroad, but have not yet appeared in this country.

What is probably the most important development in gas lighting during the past year is the introduction of a high-power single-mantle inverted lamp filling a place between the old small unit and the multiple mantle lamp. The lamp gives from 180 to 225 mean spherical candles according to the gas used and the pressure, and thus occupies a space hitherto unfilled. A valuable feature of this lamp is the fact that, because of the single mantle the light is concentrated and reflectors and glassware may be designed with much greater precision than with the multiple mantle lamp.[35]

Hitherto one of the difficulties in connection with the use of high-pressure lamps was the heat developed which limited the kinds of glassware available and also necessitated a globe of very great size. In a modification of one of the high-pressure inverted lamps now in wide use, particularly in England, a small silica cup about 5 inches high, and therefore but little larger than the mantle itself, has been substituted for the globe hitherto used. This cup totally excludes the secondary air supply, all air for combustion being admitted as primary air. The lamp, moreover, is greatly reduced in size and the reflector is omitted. It is claimed that after allowing for the absorption of light by the silica cup a 10 per cent. increase in efficiency is obtained. These cups are made for lamps of from 60 to 1,500 candle-power. They are very durable and will not break if the mantle gives way and the flame strikes them.[36, 37]

A new high-pressure lamp has also been developed in the United States, designed particularly for street lighting, and working under a pressure of 55 inches of water or 2 pounds per square inch. These lamps are at present made in two sizes—500 and 1,100 candle-power respectively and have an efficiency of over 50 candles per foot of gas per hour. The mantles are of artificial silk and have a life of over 400 hours with practically no depreciation in candle-power.[38] High pressure lighting, how-

[35] *Lighting Journal* July, 1913.

[36] *Journal of Gas Lighting*, February 18, 1913.

[37] *Journal of Gas Lighting*, February 25, 1913.

[38] *American Gas Light Journal*, December 30, 1912.

ever, has not been developed in the United States to the same extent as abroad.

The artificial silk mantle is steadily coming into use, its durability, long life and strength being its recommendations. By a recent improvement in this type of mantle, it can be burned directly on the burner, so that all burning off, collodionizing, etc., becomes unnecessary.[39]

A most interesting and valuable investigation was made to determine the cause of the falling off in candle-power of the incandescent mantle. Microscopical examination showed that when new the ash seemed to be made up of very small particles, making an opaque and light giving structure. As the mantle was heated, these particles gradually fused together to form larger particles and, by degrees a large transparent mass, which, by the laws of physics, is comparatively without light giving properties.[40]

Other experiments were made to apportion to each part of the lamp its share of the deterioration. Under favorable conditions, the deterioration in 1,000 hours' continuous burning was:

	Per cent.
For the mantle alone	2½
For the burner alone	2½
For the glassware alone	10
Total deterioration	15

of which, by proper maintenance, 12½ per cent. could have been eliminated.[41]

Automatic gas ignition is having a steady growth. Pilot lights are increasing in number, while the jump-spark and filament igniters are gradually coming into use. Distance control by means of electrically operated gas cocks and also pneumatic control in connection with pilot and jump-spark ignition are being extensively employed, particularly in the past year. It should be noted here that pilot lights have been improved by adopting the bunsen principle and by better protection, so that the danger of extinction is greatly reduced. Self-kindling mantles are also receiving attention, and one improvement recently made in this type of mantle was to mix ammonium chloride with rhodium

[39] *Gas World*, February 1, 1913.
[40] *Lighting Journal*, April, 1913.
[41] TRANSACTIONS Illuminating Engineering Society, December, 1912.

chloride. The metallic rhodium deposited is of a silver grey and comes to full intensity without presenting a dark streak down the mantle. It has since been found that lithium chloride is cheaper and works better.[42]

The pyrophoric alloys are also in process of development, and are now on the market. A new composition of the alloy has been found which, instead of giving a shower of sparks, produces a long flame, thus rendering the friction wheel unnecessary. This alloy is air proof, and does not disintegrate like the old cerium alloy.[43]

ACETYLENE.

The use of acetylene is increasing for isolated buildings and for distribution from a central plant in very small towns. A large number of burners are available to suit varying needs, but as yet no incandescent burner has been devised for use with acetylene that is thoroughly satisfactory. An enormous field for acetylene has been developed in lights for automobiles, where acetylene dissolved in acetone is dividing honors with the tungsten lamp. It is also stated that acetylene mixed with oxygen and used on a special disk of ceria gives a light almost equal to the electric arc and will shortly be put to use with the cinematograph.[44]

SUNDRY SYSTEMS.

Air gas systems and systems employing kerosene under pressure for use in connection with incandescent mantles are making considerable progress in the rural districts and other places not reached by city gas and electric plants. The former system, however, has had a setback in the increased price of gasoline and the difficulty in obtaining the high grade necessary. A new modification of the latter system consists of a gas arc lamp connected with the fuel tank by a fine flexible bronze tube. Laboratory tests showing 1,220 candle-power are claimed for this lamp.[45]

A new method of utilizing natural gas has recently been

[42] *Gas World*, February 15, 1913.
[43] *Journal of Gas Lighting*, September 17, 1912.
[44] *Gas World*, January 18, 1913.
[45] *Iron Age*, January 23, 1913.

brought out, but is still in an experimental stage. The plan is to pump the nearly exhausted wells and treat the gas in such a way as to produce a volatile liquid which, on release of pressure would evaporate into a utilizable gas.

COLD LIGHT.

The startling announcement has been made that the long looked for secret of obtaining a cold light has been discovered in France, it being understood that the term "cold" is purely relative. A rotating wheel carrying a number of lamps at the circumference is arranged so that an electrical contact lights each lamp in succession. The result is a series of instantaneous flashes as each lamp passes the contact point, retinal persistance giving the effect of a steady light. With this apparatus, the inventor claims to be able to run the lamps at a voltage of from two to four times the normal, and to obtain an efficiency thereby of 0.2 watt per candle, 2 watts per candle being normal.[46] In this connection, it may be said that the idea of supplying lamps with intermittent current is not new. Some fifteen years ago an inventor placed in the lamp circuit a commutator by which the current was interrupted a number of times a second, but nothing ever came of the plan. A test of the present system is on record from which we learn that the results are what might be expected from overrunning the voltage; the life of the lamps was reduced from one thousand hours to four hours.[47]

LUMINOUS ANIMALS.

The firefly is still the subject of research among scientists.[48] It is pretty well known that certain animals and insects have the power to produce by means of chemical reactions a form of radiant energy lying practically within the limits of the visible spectrum, but the nature of these reactions is not yet known. One investigator, indeed, separated out two substances called by him eluciferase and luciferine respectively which, when mixed and moistened, became luminous.[49] The nature of these substances is, however, a matter of doubt. A study has been made

[46] *Scientific American*, May 31, 1913.
[47] *Journal of Gas Lighting*, May 13, 1913.
[48] *Lighting Journal*, January, 1913.
[49] Philadelphia *Publc Ledger*, April 6, 1913.

of the intrinsic brilliancy of the glowworm or larva of the firefly, which gave as a result 0.0046 candle per square centimeter. From this it was calculated that the luminous material of the glowworm, could it be reproduced, would not only be of high luminous efficiency but would also be a happy mean in intrinsic brightness, far lower than the artificial light sources with which we now try our eyes, yet high enough to permit its use without pre-empting more wall space than we now give to windows.[50]

PHOTOMETRY.

The search for a primary standard of light still goes on, and the requirements for one have been the subject of papers appearing from time to time during the past year. But little actual progress in this direction has, however, been made public.

At the last meeting of the German Illuminating Engineering Society, however, a paper was read discussing the question of an absolute standard, and it was proposed to investigate the distribution of energy in the spectrum of the source of light to be investigated, to determine the sensibility curve of the human eye for different wave lengths, and to calculate therefrom the distribution of light intensity in the spectrum, and finally to arrive at the total candle-power. An extended discussion of the possibilities of using the black body as the basis of a rational unit of light followed the reading of this paper.[51]

The past year has been noteworthy in regard to the paucity of published reports on secondary standards. In the National Physical Laboratory of England a set of twenty-four tungsten substandards running at 1.5 watts per candle has now been established on a satisfactory basis. The values of candle-power which are now assigned to these lamps have been determined by a "cascade" method by six different observers, the work having been in progress for about three years. In the cascade method it was found that the mechanical errors and those due to changes of observers from day to day have given rise to a probable error of 0.08 per cent. The possession of a series of substandards graded in the hue of the light emitted has been found a valuable asset in the testing of lamps of different types in

[50] *Lighting Journal*, February, 1913.
[51] *Journal fur Gasbel.*, July 12, 1913.

enhancing the accuracy and facilitating the testing of such light sources as acetylene lamps, gas mantles, flame arcs and metallic filament lamps of all kinds.[52]

Tests were also made upon helium tubes, which indicated that the maximum deviation in the tubes tested, and which were selected with care as to uniformity of bore and thickness of wall, was 3 per cent. The chief improvement now to be sought is complete freedom from striations.

In phases of photometry other than in regard to standards, the work during the past year has been on greatly varied lines. Conveniences in working the present type of photometer, selenium and other photo-electric cells, the reliability of the flicker photometer, and the application of the radiometer have all been the subject of study.

The photo-electric cell particularly has received much attention. Of great importance is the development of a new form by the pioneer investigators of this cell, in which the alkali metal surface is covered by a layer of hydride. This is made permanent by filling the glass bulb with a rarefied atmosphere of argon or helium. These special cells possess extremely great sensibility.

Recent experiments undertaken to determine the relationship between the photo-electric current and the intensity of illumination have shown a direct proportionality over a range of illumination from about one-third that due to full sunlight down to the lowest illumination detectable by the eye.

Other experiments have had for object the explanation and elimination of a number of disturbing factors variously called dark currents and contact electromotive force effects. It now appears probable that in the photo-electric cell, when completely developed, we shall have an objective photometer of very satisfactory character.[53]

The selenium cell has been developed to such a point that it gives excellent results with monochromatic light, provided the exposure is short. An accurate sensibility curve has, moreover, been established from which it was found that the cell was most sensitive to yellowish-green light under faint illumination, and to red light under strong illumination. The relations are, however,

[52] *Electrician*, June 27, 1913.
[53] *Physik. Zeitsch.*, August 15, 1913.

so complicated that, except for monochromatic light the selenium cell is as yet impracticable for photometric work.[54]

The efficiency of a selenium preparation used as a detector of light may be defined as the amount of additional conductivity imparted to it by the unit of incident light. Later investigations show that the total effect of the light action is shown to be proportional to the square root of the incident energy, while the instantaneous effect is proportional to the energy. This is verified down to an illumination of 0.00001 meter-candle. It is shown that selenium is the most efficient light detector known, and is capable of discriminating minute differences of luminous intensity far beyond the capacity of the eye.[55, 56, 57]

Color photometry has of late occupied much attention. A chromoscope was devised a couple of years ago in which the color could be determined in terms of the colors obtained from the standard quartz plates by polarized light. In a newer instrument four numbers are required to designate the color under test as to tone, saturation and brightness. The quartz plates are in two systems, but a wide range of color measurement can be made using one system only. The author of the article describing the instrument considers it of the greatest advantage that a color can be reproduced at any time from its four characteristic numbers alone.[58]

A series of experiments made to ascertain the form of optical instrument most suitable for color measurement showed that any color could be imitated by the admixture in suitable quantities of the lights of three suitably chosen narrow regions of the spectrum. Instead of adding these colored lights, broader primaries may be subtracted from the white light by the selective absorption of suitably chosen dyes, but in this case the difficulty of expression becomes serious owing to the impossibility of securing dyes which will absorb one primary region and transmit the remainder of the white light in equal proportions.[59]

About a year ago a simple method of comparing the colors of

[54] *Electrician*, December 6, 1912.

[55] *Electrician*, July 11, 1913.

[56] *Proceedings* Royal Society, August 19, 1913.

[57] *Elec. Rev. and West. Elect.*, February 1, 1913.

[58] *Ann. der Physik.*, October 15, 1912.

[59] *Proc. Phys. Soc.*, October, 1912.

artificial illuminants was described, based on the observation of their comparative intensities through a photometer. In the eyepiece of the instrument blue, green, yellow, red and deep-red glasses are inserted successively, and in this way comparisons were made of the spectrum intensities of these colors.[60]

In connection with color photometry, the flicker photometer has received its share of attention and a discussion has taken place as to whether this type does actually measure relative light intensities. It has already been pretty well established that it gave more consistent results when used to measure lights of dissimilar colors, but there was a question as to whether there was not a "luminosity sense" distinct from the "color sense."[61] Recent careful investigations indicate, however, that the flicker photometer gives true brightness, although it gives at low intensities a reversed Purkinje effect which makes it necessary to use caution in its employment.[62]

It has been suggested that the physiological process, which affords the common basis by which colored and uncolored lights are measured by means of the flicker phenomenon, is the contraction of the iris when exposed to bright light. According to this the flicker adjustment would be complete when the iris has no tendency to alter under alternating illumination. An experiment was made in which the irises of the observers were paralyzed with a solution of homatropine sulphate. The appearance of the flicker was, under these conditions, just the same as when seen by normal eyes. All degrees of flicker remained as before the atropine was placed in the eyes, and it was noted that the disagreeable quality of the coarse flicker persisted undiminished. Moreover the numerical results obtained for each eye and for each observer agree very well among themselves.[63]

One writer claiming to have a practical solution of the problem of heterochromatic photometry describes absorbing liquids, definitely specifiable, which may be used in varying thicknesses and proportions to make the light of a given standard like that of any other illuminant. A yellow and a blue solution have been found which suffice to match all the ordinary illuminants with a Carcel;

[60] *Good Lighting*, August, 1912.
[61] *Philos Mag.*, November and December, 1912.
[62] *Electrical World*, April 19, 1913.
[63] *Philos Mag.*, July, 1913.

a purple solution is suggested for use where these are not sufficient, the three absorptions giving by the three-color principle all the tints as represented in a color triangle.[64]

A suggestion made to eliminate color difference in the photometry of incandescent lamps is to run the standard lamp at such a voltage that its color corresponds to that of the lamp under test, and then determine the candle-power of the standard from a previously plotted curve of candle-powers and voltages.[65]

To the number of illuminometers already on the market has been added still another. This consists of a box containing a small standardized tungsten lamp at one end and a bunsen screen at the other. On one side of the box is a sliding rheostat connected in series with the standard lamp and provided with a pointer indicating on a scale the illumination on the screen in foot-candles, the adjustment being made entirely by varying the resistance. Two scales are provided, one reading from 0.3 to 10 foot-candles, the other from 0.001 to 0.3 foot-candle, corresponding with the application of 4 and 2 volts respectively to the standard lamp.[66]

Still another recent illumination photometer consists of a Lummer-Brodhun arrangement with lateral windows to which are attached two rectangular tubes, one directed toward the screen upon which the illumination is received and which may be set at any angle and in any plane, and the other terminating in an elbow leading to a standard tungsten lamp, in which elbow is set a standard reflecting screen; in this photometer the standard tungsten lamp is movable, traveling along a scale.[67]

Another photometer, depending upon the acuteness-of-vision, comprises a white wedge illuminated by the light to be tested. Between the eye and the illuminated area is placed a glass screen on which a diagram of very fine lines is marked out. In comparing two lamps the observer merely moves the photometer back and forth until the lines become perceptible and notes the distance from the source. In order to prevent imagination from assisting the eye, the lines may be rotated so that the observer does not know their position. The method is said to give satisfactory

[64] TRANSACTIONS Illuminating Engineering Society, June, 1913.

[65] *Electral Review* (London), November 15, 1912.

[66] *Illuminating Engineer* (London), December, 1912.

[67] *Illuminating Engineer* (London), September, 1912.

results, but allowance has to be made for the effect of adaptation on the eye.[68]

During the year attention has continued to be given to photometers adapted to the newer requirements of the incandescent lamp industry. Two watt-per-candle photometers have been described having for their object determination of the voltage at which the lamp under test will give the desired efficiency rather than the candle-power, as was the former practice. One of these is noteworthy in that the operation of the instrument is exactly parallel to the operation of the formerly widely used candle-power photometer as used upon single circuit fluctuating voltage.[69]

Another watt-per-candle meter has been devised based upon the principle that if two potential differences are equal as indicated by a galvanometer, then the two lamps are at the same watts-per-candle. If they are different the variation in a resistance, required to make them equal, is a measure of the ratio of the watts-per-candle of the two lamps.

A rather novel method of reducing the quantity of light for photometric purposes was described in a paper read before the German Illuminating Engineering Society. If the light used for illuminating the surface under test be reduced by placing in its path an opaque disk with an open sector, the illumination of the surface will not be uniform if the disk is stationary. The author, therefore, lets the light passing through the sector be received in an Ulbricht sphere, the inner surface of which is uniformly lighted by reflection as far as it is not illuminated by incident light. To complete the arrangement so as to have a portable photometer for white light, a white ring surface, with an opening in it is provided on the outside of the sphere. The observer changes the angle of the sector until the hole in the ring becomes invisible, thus obtaining a measure of the light by which the white surface with the hole is illuminated.[70]

A novel method has been devised to measure the energy of the ultra-violet radiation emitted by a mercury arc lamp. This is based on the fact that the coefficient of velocity of hydrolysis of

[68] *Zeit. Instrumentenk.*, September 1912.

[69] *Lighting Journal*, July, 1913.

[70] *Jnl. für Gasbel.*, July 12, 1913.

tetrachloroplatinic acid varies proportionately to the incident radiant energy.[71]

Investigators are still working on the application of photography to photometry and it is expected that an emulsion will be obtained which gives results comparable to the impression upon the eye. Means have now been developed for measuring intensities, opacities and other properties which it is necessary to know of the developed emulsion, and the different materials possible to use in the emulsion have also been investigated.[72, 73, 74]

An instrument has been devised for observing intrinsic brilliancy. This consists of a lens equipped with a "cat's eye" diaphragm throwing an image of the source to be examined on a screen inside a blackened box. By means of a Lummer-Brodhun prism, the observer can compare the brightness of the image with that of a diffusing plate illuminated by a small standard incandescent lamp. The adjustment of equality of brightness is made by means of the diaphragm.[75]

OPHTHALMOLOGY.

Many articles have appeared lately upon the requirements for hygienic lighting and the advantages of one system of lighting over another; these are largely, however, either recapitulations of previous knowledge or are inspired by the advocates of the method of illumination in question.

An investigation was made last year in regard to defects of vision among school children in Liverpool, from which it appeared that, as might be expected, vision was better among children attending schools in the outskirts where the open surroundings gave opportunity for open spaces than among those attending schools in the center of the city. With one exception the girls' sight was distinctly worse than the boys' this being attributed by investigation to the fact that the girls' course included sewing. This was regarded as the most likely of any item in the school curriculum to affect the eyes, and is often carried out under the most disadvantageous conditions of lighting. One investigator

[71] *Comptes rendus*, January 27, 1913.

[72] *Le Genie Civil*, February 15, 1913.

[73] *Comptes rendus*, February 3, 1913.

[74] *Elek. u. masch.*, May 25, 1913.

[75] *Comptes rendus*, April 21, 1913.

thinks it would be desirable if sewing could be abolished altogether under the age of seven, and further urges that there is not enough discrimination during sewing lessons between children whose eyesight has been found satisfactory and those with serious defects.[76]

Similar investigations have been carried on in other countries. While it has been shown that conditions producing defective vision are now much more closely studied than heretofore, and that defective conditions are being remedied, the percentage of children suffering from poor sight is still large. Such subjects as size and style of type, quality and color of paper, illustrations, angle, position of reading, and color of blackboard and chalk have all been, and are still being studied, particularly with reference to saving the sight of the children.[77]

A series of experiments was made to determine the perception of lights of short duration, the assistance of seventeen observers of different ages and occupations being enlisted. From the results obtained a curve was plotted showing the perceptibility of flashes of light in terms of the durability and intensity.[78] Tests were also made by other experimenters along the same line.[79]

An interesting investigation was recently carried on by a French journal to find the combination of colors most legible at a distance. The order of merit is somewhat surprising, the best being black on yellow, while the customary combination of black on white appears sixth in a list of thirteen.[80]

A somewhat similar test was made to find, if possible, the most legible type to use for books and periodicals. The type proving best was the one selected by our newest illuminating engineering journal, while a rather startling conclusion was that the American typewriter stood in a class by itself as the worst.[81]

Two experimenters have recently published the outlines of recent researches lasting over a year upon the effects of radiation upon the eye, most of the tests being made upon rabbits. The

[76] *Good Lighting*, September, 1912.

[77] *Ophthal. Record*, February, 1913.

[78] TRANSACTIONS Illuminating Engineering Society, November, 1912.

[79] *Electrical World*, August 9, 1912.

[80] *Scientific American Supplement*, February 15, 1913.

[81] *Lighting Journal*, January, 1913.

light sources chiefly used were the quartz-tube mercury arc lamp and the magnetite lamp. Much of the information obtained is not yet in shape for publication, but it was shown plainly that under the ordinary commercial conditions surrounding the use of even the more brilliant illuminating agencies, no specific danger exists; and that only by the grossest neglect and deliberate protracted exposure of the eye to the brilliant light sources at close range is there the slightest chance of injury to the organs of vision, except in so far as temporary injury may be due to the effect of ordinary visible radiation.[82]

Tests using commercial light sources and commercial colors were also made to determine the effect of a colored background upon visual perception. The results were not fully reported, but they showed that the intensity of reflected light from an object is a much more important factor in perceptibility than color.[83]

Investigation of the perception of color shows that the duplicity theory can no longer be held, but that all facts harmonize with the theory that the rods are the organs which are concerned in the perception of colors of short wave lengths.[84]

It has frequently been said that with natural lighting out of doors, a higher intensity of illumination is necessary than with artificial lighting. A series of tests were made at sunrise and sunset on a number of observers, from which it was shown that daylight illumination in the open is satisfactory for reading at all intensities as low as with artificial light, and probably lower.[85]

ILLUMINATING ENGINEERING SOCIETIES.

Since the last meeting of the Illuminating Engineering Society, another national illuminating engineering society has been formed:—the Deutsche Beleuchtungstechnische Gesellschaft. This is the third association of the sort in existence, these being, in order of time of formation, the American, British and German. The first general meeting of the new society was held in the physical laboratory of the University of Berlin on Feb. 24, 1913. Among the papers presented were: "The Eye and Il-

[82] *Electrical World*, May 24, 1913.
[83] *General Electrical Review*, April, 1913.
[84] *Arch. of Ophthal.*, March, 1913.
[85] *Electrical World*, July 5, 1913.

luminating Engineering," "Light Units," "The Boiling Temperature of Carbon in the Arc Lamp," "Method of Diminishing the Light Intensities in Photometry," "A New Method of Determining the True Temperature of Filaments in the Incandescent Lamp," and "The Present Disadvantages of the Sphere of Automobile Lighting."[86, 87, 88]

A gratifying announcement is that of the reorganization of the International Photometrical Commission. This was organized by the International Gas Congress in 1900, and held its first meeting in Zurich in 1903. This was composed of representatives of gas companies with the co-operation of certain of the national laboratories. It is now proposed to extend the commission to include not only the gas interests but also the electrical interests, and to be representative of these industries, illuminating engineering societies and other associations interested in photometry and illumination and to be responsible to them. A subcommittee has already been appointed to consider photometrical units and standards.[89,90]

The British Illuminating Engineering Society has partly completed a study of school and library lighting with a view to formulating recommendations suitable for general adoption. Committees of this society, in co-operation with committees of the Association of Teachers in Technical Institutions and the Library Association have issued preliminary reports on the artificial lighting of schools and libraries calling attention to a number of important features frequently overlooked, prominent among which is glare. Recommendations as to minimum illumination for various purposes were made.[91]

RELATIONS OF ILLUMINATING ENGINEERNG TO OTHER BRANCHES.

Illuminating engineering is gradually coming into recognition by other professions and arts. The architect is beginning to appreciate the value of a knowledge of the principles of illumination in decoration and utility, as is shown by the co-operation

86 *Journal of Gas Lighting*, December 10, 1912.
87 *Electrical World*, April 26, 1913.
88 *Elek. Zeit.*, June 26, 1913.
89 *Journal of Gas Lighting*, December 17, 1912.
90 *American Gas Light Journal*, November 11, 1912.
91 *Electrician*, July 25, 1913.

of the architect and illuminating engineer in planning the lighting features of the coming Panama-Pacific Exposition in San Francisco, and in designing the illumination of many important buildings, such as libraries, churches, restaurants, etc. At the International Congress of School Hygiene just held in Buffalo, two sessions were completely turned over to the Illuminating Engineering Society and presided over by a representative of that society. The theatres are also coming to the illuminating engineers for their scenic effects; and in one installation of especial interest, where the services of an illuminating engineer were enlisted, gauze scenery and dyes were used in preference to canvas and paint, and instead of using dipped lamps the effects were produced by color screens. The lighting arrangement is such that the lighting of the scenery is entirely separate from that of the actors so that while the scenery passes through a very large range of color changes, the color of the light on the actors remains constant. Furthermore complementary spots are used to correct the color of the actors' faces when colored light has to be used on the stage proper. In this installation the use of the arc lamp has been entirely abandoned and the concentrated filament form of tungsten lamp used entirely. Footlights have been largely given up and the lighting of the stage is arranged to produce natural effects by lighting from overhead by front lights in the gallery and by lights directed from one side of the stage so as to produce normal shadow effects. It is interesting to note that these changes reduced the maximum load from 45 to 5 kw.

Manufacturers are taking up the question of lighting their shops and mills, and have investigated the influence of the character of the light on the time taken to perform mechanical operations. One of our large lamp concerns recently sent a letter of inquiry to a number of industrial concerns; of the 209 replying, 164 said that improvements had been made in their lighting, and a large number of expressions of opinions were received to the effect that increased production, better goods, and greater satisfaction on the part of the workers had been the result. Moreover, in many cases the cost of lighting has been reduced.[92]

[92] *Journal of Gas Lighting*, February 11. 1913.

Merchants have been employing the illuminating engineer to such an extent that it is rare that a periodical devoted to the lighting industry does not contain a description of the lighting features of some large store in which the installation was carefully planned and well carried out. This applies also to most establishments depending for their success upon the general public.

That the work of the railway mail clerk is one of the most trying occupations as far as the eyes are concerned is now recognized, and the Post Office Department has issued specifications for lighting the mail cars, covering location of light source with regard to the initial illuminating values, absorption by globes and reflectors, light failures, emergency lighting, etc.[93] The data for these specifications were obtained from actual tests on a mail car of one of our large railroads.[94]

In this connection it may be well to mention that an exhaustive test has been made at the shops of one of our large railway systems to standardize the best method possible of train lighting. This test was made under the auspices of the Association of Railway Electrical Engineers.

The relation of lighting to the number of accidents has also been receiving attention as never before. The intensity of the illumination and the location of the sources have been studied in connection with moving machinery, passage-ways and stairs; and in this connection it has been suggested that too much light might be as bad as too little in the dazzling effect on the eyes. A very practical illustration of the relations of light to accidents is the statement of a leading casualty company of New York that "the greatest number of accidents occur during the months of diminished light." Furthermore, a prominent official of one of America's largest manufacturing companies is authority for the statement that "insufficient illumination" is frequently held by juries to be "contributory negligence," and in the defense of accident suits the lawyers of this company find it a valuable point to offer testimony by a competent witness to prove the adequacy of lighting arrangements in this company's plants.[95]

In this connection it may be said that several states have passed

[93] *Lighting Journal*, February, 1913.

[94] *Electrical World*, March 29, 1913.

[95] *Safety*, p. 86.

laws specifying the candle-power of locomotive headlights,[96] and a number of tests, the last under control of one of the state public utility commissions, were made to find out whether the lights complied with the law and also to determine whether the headlight might endanger the safety of operation of trains through interference with signal lights or in any other way. With electric headlights, numerous phantom lights were seen, but these were of the nature of mere flashes where the engine was running at the ordinary speed. There was difficulty in distinguishing classification lights and engine numbers on locomotives equipped with arc headlights, and precautions should be taken to place these marks at such a distance from the headlight that the latter may not materially interfere with their correct reading. The arc lamp should be switched off when passing through large yards and other places where it might have a tendency to interfere with the performing of duty by yardmen or others, or to endanger their lives. An incandescent lamp should then be switched on.[97]

A report, rather startling in its novelty, has been issued to the effect that souring of milk is due to ultra-violet rays, and that milk may be kept sweet for days by putting it in a red glass bottle, or in a plain glass bottle wrapped in red paper.[98] A reverse action apparently on this order, and now creating much comment, is the use of ultra-violet rays for sterilizing water, as noted above.

A suggestion is contained in an installation of gas arc lamps for lighting tennis courts. Perfect satisfaction was obtained, and the courts were even better patronized at night when it was cool than in the heat of the day.[99] This installation paralleled a similar one in another town in which tungsten lamps were used,[100, 101] and these, in turn, were followed by a golf putting course lighted by gas. The latest item of this sort is the equipment of a polo-field which is to be lighted by forty-eight 400-

[96] *Lighting Journal*, January, 1913.

[97] *Scientific American Supplement*, February 1, 1913.

[98] *Scientific American*, June 7, 1913.

[99] *Good Lighting*, September, 1912.

[100] *Electrical World*, July 12, 1913.

[101] *Electrical World*, August 24, 1913.

watt tungsten lamps with metal reflectors, the installation being designed to give one foot-candle on the horizontal plane.[102]

INDIRECT AND SEMI-INDIRECT LIGHTING.

Indirect lighting and its half-brother, semi-indirect lighting, are progressing steadily, and numerous installations of each are illustrated in the current technical journals. Manufacturers are almost daily producing new forms of fixtures of this type, some of them artistic in the extreme. One fixture for semi-indirect lighting has a space between the bowl and upper reflector enclosed with clear glass to keep out dirt, insects, etc. This has features of value, but its artistic merit is open to question.

As a relief from the present standard, though undesirable, method of lighting railway cars, it may be noted that certain express trains now running out of New York are now provided with indirect fixtures.[103]

STREET LIGHTING.

The question of street lighting is attracting extraordinary attention. People are no longer satisfied with just enough light to see to move around safely, but are coming to a realizing sense of the advertising and artistic values of ample light. White Ways are almost as common as towns themselves, and where the cities do not seem inclined to install them, the merchants put them in by private subscription. The open arc lamp is a back number, and in many cases the enclosed arc, once so universal, is giving place to magnetite or flaming arcs, or to clusters of tungsten lamps on ornamental poles. The old, severely plain iron or wooden pole is rapidly giving way to the artistic post, and there is a strong tendency to recognize the artistic as well as the utilitarian.

While much publicity is being secured to ornamental lighting, the majority of the business, however, has been connected with the ordinary street lighting, which is, in the electric field, practically working in the direction of the use of the luminous arc lamp, and the tungsten filament incandescent lamp. The increased standard of general street lighting has been largely accelerated by the reduced cost of light, and while it has taken on no dis-

[102] *Lighting Journal*, May, 1913.
[103] *Electrical World*, April 26, 1913.

tinctively new form, the standard of lumination intensity (not necessarily size of units) has been raised very considerably.

An interesting test was made in Switzerland to find the relative advantages of arc and metallic-filament incandescent electric lamps. Two streets of equal length were lighted with 10-ampere electric lamps and 500-candle incandescent lamps respectively. The choice between the two forms of lighting was left to 29 trolley car motormen. Of these 25 favored the metallic-filament lamp on account of lessened glare and irritation to the eyes.[104] The mercury-vapor lamp has been suggested as a street lighting unit, but thus far its use for this purpose has been hardly more than a suggestion, although in one city lighted by a municipal electric plant, a group of merchants installed six quartz tube lamps to show by contrast the poor character of the general street lighting.

During a "street show" in one of our large cities, ornamental pillars each carrying three electric light globes were erected. Panels in these columns were made transparent by making them of wire netting and coating them with varnish of various colors, giving the effect, when lighted from the inside, of art glass.[105]

In the ornamental lighting system, it is frequently desirable to turn off the lamps without affecting the rest of the circuit. This is done in at least three towns by various systems of pilot wires and magnet switches centering at the central station or other convenient point.[106, 107, 108] In this connection may be noted a method of controlling from the central station switches on a network by superimposing a ripple on the regular voltage.[109] In another town a switchboard has been placed in the office of the chief of police so that in case of burglary or fire alarm after the regular time of shutting off, the ornamental system of street lighting may be turned on.[110]

An unfortunate dispute has arisen in one of the large cities of England over the relative merits of high pressure gas and flaming arc lamps. Two streets were lighted by the rival illuminants and

[104] *Electrical World*, April 26, 1913.
[105] *Electrical World*, October 12, 1912.
[106] *Electrical World*, November 30, 1912.
[107] *Electrical World*, September 7, 1912.
[108] *Electrical World*, September 14, 1912.
[109] *Electrician*, February 14, 1913.
[110] *Electrical World*, October 12, 1912.

experts representing each of the industries made illumination measurements and prepared reports. The tests were entirely in favor of the electric lamps, but the fact was brought out that the gas lamps were improperly adjusted and installed, so that no conclusions could be drawn as to the relative merits of the two systems. The whole affair caused much argument and a good deal of acrimonious discussion on the part of the advocates of the two systems.[111, 112]

Gas street lighting has made great strides in both England and continental Europe, where high pressure lighting is in great favor. Automatic lighting of gas lamps is also making rapid progress on the other side of the Atlantic, the lamps in a large number of towns being equipped with these appliances. Two systems of automatic lighters are in extensive use, one being operated by a momentary addition to the street main pressure and the other by means of a clock arrangement on each post so that the lamps operate individually and independently. Highly encouraging reports as to the satisfactory and economical working of these systems have been made.

In this country street lighting by gas, while making steady progress, has not experienced the rapid growth that is so marked abroad. Automatic lighting has not as yet obtained a foothold here, and except for two minor installations, there is no high-pressure street lighting. Another difference between European and American practise is that abroad inverted burners are becoming the universal practise, while here, except for a two-mantle 150 candle-power lamp, the inverted burner is not used.

Ornamental street lighting by gas is spreading, a number of prominent installations having been made.

It may be of interest to note that one of our public utility commissions, which had been investigating the street lighting in a large city of the state, recommended that the city employ an illuminating engineer, to be retained permanently if possible, for the purpose of selecting the type of lamps to be used and to fix their location.[113]

Increased interest in street lighting does not seem to be unusual,

111 *Journal of Gas Lighting*, October 5, 1912.
112 *Electrician*, March 7 and 14, 1913.
113 *Electrical World*, January 18, 1913.

however, as a recent item in a French technical journal contains the statement that in that country, out of 10,000 villages or communes of more than 1,000 inhabitants, 6,000 are without public lighting.[114]

FIXTURES, GLOBES AND REFLECTORS.

Architects and decorators are realizing more and more the importance of artistic and appropriate gas and electric lighting fixtures, and new designs adapted to all conditions are daily appearing on the market. One type that is especially popular just now is the "shower" chandelier, and designs of great beauty have been brought out. Another new design is an indirect lighting portable which may be used as an ornamental table light.[115] Still another fixture designed to give a strong concentrated light for fine work consists of a small reflector socket carrying a tungsten lamp and welded to substantial brass tube bent so as to fit closely the body of the machine in connection with which it is to be used. This tube is securely fastened to the machine and becomes practically part of it.[116]

A novel fixture has been installed in the rotunda of one of our state buildings, and is probably the largest chandelier ever built. The fixture body is over sixteen feet high and is suspended by a chain seventy-two feet long, consisting of twelve-foot links containing special tubular tungsten lamps to give the effect of a string of light, the joints in the chain being provided with ball lamps in decorative design. The fixture itself is finished in composition silver leaf. In some of the reading rooms of the same building indirect lighting has been used with the bottoms of the basins made of pink Georgia marble, thus producing very beautiful effects. The general illumination of these rooms is low, and so each table is provided with reading lights designed by actually placing an individual at the table with a book and adjusting the lamp for his comfort.

In another installation in an office building an attempt was made to reproduce artificial daylight through a false skylight matching the color received through an actual skylight in an adjoining room. The lighting is so arranged that at night, when

[114] *L'Electricien*, January 11, 1913.
[115] *Electrical Review* and *West. Elect*, March 1, 1913.
[116] *Electrical World*, November 2, 1912.

artificial light is used, the color of the illumination will be adjusted to match the artificial lighting.

In connection with the use of marble for diffusing material noted above, it is reported that patents have been taken out in Germany for using marble instead of glass. Marble is planed down until it became translucent and different intensities of light were shown from behind. The effect obtained was that the illumination was hardly distinguishable from daylight, and it was difficult to realize that the room was artificially lighted.[117]

Under this head might be mentioned efforts recently made to increase the brilliancy of moving pictures. The available sources of light having about reached the limit of their intensity, the reflecting power of the screens is now receiving attention. The early muslin screens were replaced with canvas coated with a layer of white; ground glass, which was next tried, was found too fragile, and was in turn replaced by a fabric coated with aluminum powder giving a screen presenting a silvery surface of great uniformity. The new screen is 3.7 times as luminous as the muslin.[118]

An investigator conducted a series of tests to determine the distribution of light in an ordinary room. Under the conditions of the test it was found that the light was strongest in the upper and lower part of the room and less intense throughout the middle portion. Working on this idea, a translucent screen was made in the form of a vertical half cylinder placed close to the wall; between it and the wall was set the light source. Measurement of the light distribution under these conditions showed that it was almost identical with that obtained from daylight.[119]

About the first of last year a screen was brought out which filtered the rays of the electric arc light in such a proportion that those rays passing through it formed a true daylight color. This was followed a short time ago by a similar screen for the incandescent gas lamp. The resulting light is a perfect match for average daylight, and by it colors may be judged with perfect accuracy.[120]

[117] *Good Lighting*, January, 1913.
[118] *Good Lighting*, January, 1913.
[119] TRANSACTIONS Illuminating Engineering Society, June, 1913.
[120] *Lighting Journal*, May, 1913.

PHYSICS.

Previous determinations of the constant of the Stefan-Boltzmann law of radiation vary from 5.3 to 6.5. During the past year, two independent investigations were made from which new figures for the constant were derived.[121, 122]

Another investigator describes experiments showing the deviation from Lambert's cosine law of tungsten and carbon at glowing temperatures. It was found that the brightness of tungsten, beginning with normal emission, increases with the angle of emission, reaches a maximum at about 75°, and for larger angles diminished rapidly. The brightness of carbon, beginning with normal emission, decreases with increasing angle of emission, the rate of decrease increasing with the angle. The relative brightness variations for tungsten at the higher of the two temperatures chosen are about 20 or 25 per cent. greater than the corresponding variations for the lower temperature. No definite change was found for carbon.[123]

An experimental lecture was delivered late last spring before a European society on the relations between spectral analysis and the electronic theory. The fundamental point was that what oscillates in light is nothing but electrons. The lecturer also discussed optical resonance as deduced from the theory of electrons and the Zeeman phenomenon.[124]

LEGISLATION.

An appreciation of the importance of proper illumination is growing on the legislative bodies of different countries, and investigations are being held and laws passed governing particularly the lighting of factories and workshops. In Holland, the law specifies that the employment of women and young children is forbidden in works in which artificial light is normally required between 9 a. m. and 3 p. m. An illumination of 1½ foot-candles is specified as the minimum for certain processes exceptionally trying to the eyes, and a minimum of one foot-candle in less exacting occupations.[125]

121 *Electrician*, December 20, 1912.

122 *Deutsch Phys. Gesell.*, November 15, 1912.

123 *Astrophys.*, December, 1912.

124 *Elek. Zeit.*, April 23, 1913.

125 *Iron Age*, August 17, 1912.

In England, a special committee has been appointed by the Home Secretary to inquire into conditions necessary for adequate and suitable lighting of factories, and in France the question has been under discussion for about two years.[126, 127]

In our own country the New York State Factory Investigating Commission has been studying the lighting of workshops for two years,[128, 129, 130] and a bill has been drafted with the aid of a committee from this Society for its regulation. The Industrial Commission of Wisconsin last January issued its general order on sanitation which included ventilation and shop lighting. This order provides for daylight illumination and specifies the minimum illumination under different conditions.[131]

PHOTOGRAPHY IN ILLUMINATING ENGINEERING.

An interesting lecture was delivered not long ago illustrating the value of photography in illuminating engineering. The speaker laid stress on the difficulty of obtaining good photographs by artificial light, and said that there was little information available as to what the exposure ought to be or how to allow for the actinic values of the different kinds of light. The two essentials in a good photograph of an installation are that the room shall appear exactly as it really is by artificial light, and that the positions and natural appearance of the fixtures shall be shown without halation or distortion. The lecturer believes that the ideal way to preserve a good record of lighting installations is to have a really good photograph showing the actual installation as it appeared to the eye and also data on intensity of illumination.[132]

In another lecture on photography by invisible light, the speaker said that the longest infra-red rays thus far measured (those of the quartz) have a wave-length of 0.3 mm., while the shortest electrical waves observed are 2 mm. in length, indicating a brief undiscovered gap between the two sets of phenomena. The lecturer showed ultra-violet photographs of the invisible

[126] *Journal of Gas Lighting*, January 28, 1913.

[127] *Electrician*, January 24, 1913.

[128] *Gas World*, December 14, 1912.

[129] *Journal of Gas Lighting*, December 17, 1912.

[130] *Electrical World*, December 28, 1912.

[131] *Gas Age*, March 15, 1913.

[132] *Illuminating Engineer* (London), December, 1912.

electronic discharge which proceeds from the ordinary electric arc and not detectible to the eye. A current of air diminishes the intensity of this discharge within its own range, but does not affect the streamers beyond. The ultra-violet photographs presented were most interesting in showing the diffusion of the ultra-violet shadows even in full sunshine. Ordinary glass is practically opaque to light of this short wave-length, while the pigment "Chinese white" appears black under its illumination. The lecturer's lunar photographs also show hitherto invisible patches of heterogeneous material near one of the craters indicating strongly the possibility of sulphur deposits and so contributing to the evidence of their volcanic origin. The infra-red landscape views were remarkable for their black skies and strong shadows and for the snowy whiteness with which the green foliage appears, owing to the deep-red component of its chlorophyl coloring matter.[133]

ILLUMINATION MEASUREMENTS AND CALCULATIONS.

Some study has been put upon methods of determining and calculating illumination under various conditions, and a number of ways of shortening and simplifying existing means have been put forth. One writer suggests that if a curve be plotted in which the y-axis, corresponding to the relation of the intensities of the lights, be divided to a logarithmic scale, and the x-axis, corresponding to the distance from one of the lights to the screen, be divided to a natural scale, the resulting curve will have a much more useful character than if drawn on ordinary graph paper.[134]

A method has been worked out for determining the illumination at any point on a flat surface illuminated by a source above it. The method consists in dividing up the surface into areas each corresponding with a unit solid angle. By means of the formulae and tables given, the illumination can be calculated more exactly than by the approximate methods generally employed.[135]

One author criticises the present method of laying out the light distribution curves of any source, and recommends an illumination distribution curve in which the lengths of the polar ordinates are proportional to the product of the intensities into the areas

[133] *Electrical World*, February 8, 1913.

[134] *Archiv. für Elektrotechnik*, I, 1912.

[135] *Elektrotech. Zeitsch.*, December 19, 1912.

of the zones in which the rays are taken. The same writer calls attention to the fact that an error is introduced in the illumination measurements by neglecting the more or less efficient utilization of the reflected light according to the angle of emission from the light source.[136]

Respectfully submitted,

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DISCUSSION.

PROF. GEORGE A. HOADLEY:—After hearing this report I am more than ever convinced that I have not fully appreciated the progress of illuminating engineering. I have just one remark to make in regard to photography for establishing standards of light, and what I have to suggest, I suppose has already been done. I speak of it simply because I am not sure. Those of us who are accustomed to practical work in photography know the tremendous difference there is in the results obtained dependent upon the condition of the illumination of the subject, and upon the length of time of exposure. If we are going to have anything at all that will give us standards along the line of actual illumination through photography, a standard time of exposure and condition of illumination must be agreed upon.

[136] *Progressive Age*, December 2, 1912.

THE PSYCHIC VALUES OF LIGHT, SHADE, FORM AND COLOR.

BY F. PARK LEWIS, M. D.

Synopsis: In its last analysis the physics of light must be considered in the effect of shade, form and color upon the human emotions, feelings and sensations. No single factor more definitely dominates the lives of men than the impressions made upon them by what they see. The dignity and beauty of our surroundings inspire to higher living and better citizenship. We are brought in relationship to the external world only through our special senses. Were all other senses abolished while the intelligence remained, there would be no possibility of communication with the outside world. Light and color are not the waves of different amplitudes in the ether but are the results of the impressions produced upon our consciousness by these external influences. We perceive objects only by reason of the reflected light from their surfaces. Could we imagine a condition in which surfaces would reflect no light, objects could not be seen even though light were present. The element of beauty has not only an esthetic value; there are by-products, if they may be so called, which are incidentally developed and which have even a greater bearing upon our lives. In a mining district in Pennsylvania the workmen were encouraged by competitive prizes to make beautiful gardens in back-yards which had been filled with debris. The effect was not only to beautify the district and to give an agreeable change of occupation with physical betterment, but an increase of civic interest. The mental and moral effect of light and shade cannot be ignored. Excessive lighting brings out sordid details with unpleasant glare which is as bad in effect as insufficient light. The beauty of light sources should not be forgotten. Good lights for the poor will make the home beautiful. Collaboration is urged on the part of illuminating engineers, architects, school men, ophthalmologists, and others to secure broader instruction on the care of the eyes.

It would seem a far cry from the physics of illumination and its application to the affairs of civilized life to a study in psychology in one of its most subtle and illusive phases, and a word of apology and perhaps of explanation may be necessary in justification of my temerity in asking a group of practical scientists who are dealing with *real* problems and *actual* things to go so far afield from the noise and bustle of the street as to penetrate into the mysteries of the mind itself. I think you will agree with me however that the subject is not so remote nor abstract as might at first sight appear.

It makes very little difference how we may analyze the various spectra in determining their ultimate construction, or with what care we may study the nature of the light sources and the phenomena of the reflection and distribution of the luminous energy, if we fail to take into account as a primary and essential consideration the effect, not only upon the human eyes, but upon the human emotions, feelings and sensations, produced by the changes of light and shadow, of complementary and contrasted colors and the influence actually produced on our actions and conduct by the things which constantly come within the range of our vision.

There is probably no single factor which more definitely dominates our lives than the impressions made upon us by the things which we see. It makes a vital difference in his outlook on life and his attitude towards society if a man's surroundings are sordid and dirty and mean. Under such circumstances it will be hard for him to be a good citizen. What matters to him whether or not we have dignified and inspiring architectural monuments if he lives in a home but little better than a pig-pen? How can we hope that he will be interested in good government, in public art galleries, open air music, or in well lighted streets, if he goes from digging a sewer into a hovel scarcely more attractive? It is just the uplifting glimpses of beauty that take him out of the drudgery of a monotonous existence and make him realize that his own home may in simple ways be made more livable and more attractive. While this is in no sense a paper on social welfare the far reaching effect of light and shade of form and color is so great as to excuse the somewhat unusual form in which the subject is presented.

We know of course as a scientific fact that the only way in which we are brought into relationship with the things surrounding us is through the medium of our special senses, that these are the pathways through which we are made conscious of the existence of the external world. If one of these senses is lacking or deficient we must learn to depend upon the others. While there does not exist an automatic or compensatory balance by which one sense is increased in efficiency by reason of the loss of another the very necessity of depending upon those

which remain to us may, and often does, make them sharper and more quickly responsive. An almost completely blind lad whom I saw a few days ago was readily able on hearing coins jingled in the pocket to give the number of them and their denomination. This is not surprising when we recall that each piece of metal has a distinctive tone when struck against another and that it required only an alert and correct ear to differentiate the tones and to assign to each its proper value. The degree of accuracy possible when certain senses are trained was brought very vividly to my attention sometime since, when I had the unusual opportunity of spending a few hours with that rarely gifted woman, Helen Keller. Her hearing and sight were lost at so early a period in her life as to exist only as the vaguest memory. Her only remaining avenues of communication with the outside world are through her sense of touch, of taste, and of smell. The sense of taste is not highly cultivated with any of us and the opportunities in which it can be used as a method of discrimination are relatively limited and infrequent. There remain then for her only the sense of touch which has been refined to such a degree as to make it interpret to her volumes that to the rest of us are closed; and the sense of smell, which while not as keen as that of a hound, is so vastly finer than that which most of us possess that it serves as a reliable aid in a large number of circumstances to enable her to locate herself, to determine who are her companions, and in a word to bring to her mind a multitude of facts for which most of us depend upon the employment of our other senses. The thought occurred to me that if it were possible to conceive of the existence of a still further loss of perception so that there would be no method of conveying to her brain the vibrations that are carried through the floor upon which she stands, or through the trunk of a tree by which she recognizes the swaying of the branches and the moving of the leaves, —and if it were still further possible to imagine the loss of the sense of smell so that the odors which are carried on the air would convey nothing to her intelligence, and if with this were to go the sense of taste and it were still possible that all her functions could be carried on, there could remain immured within the prison walls of her body the same intelligent, responsive, percep-

tive, even intutive intelligence that now exists; but there would be absolutely no method by which she could be brought in conscious communication with the outside existing world. Indeed so far as she is concerned there would be *no world* because its existence is predicated upon its recognition by the intelligence and sensation within. The impressions which are conveyed to us therefore by our senses are tangible and real only to the degree that they are recognized and understood.

It is a very old subject of discussion as to whether sound would be produced if a bell were rung out at sea where there were no ears to hear it; or if in the absence of eyes the trees would still be green and the poppies red or the rainbow, when right conditions exist, still in the sky. Of course there is neither sound, nor light, nor form, nor color in the absence of an intelligent recognition of these qualities because it is not the motion in the air produced by the pounding of the hammer upon the bell which constitutes sound; it is the impact of these atmospheric waves upon the tympanum carrying an impression through sentient nerves to special brain centers and the transformation of these impressions into a conscious recognition of that which we understand as the sound produced by the ringing of the bell. The colors of the rainbow are *not* the vibrations in the ether of wave-lengths of the different amplitudes, but the result of the impressions which these vibrations produce upon the retina, exciting sensations in the rods and cones which are conveyed through the optic nerves to the visual area and are there interpreted into our conscious understanding of that which is known to be the red, the yellow, the orange, the blue, the green, the indigo and the violet.

In a recent discussion before the Oxford Ophthalmological Congress on "Nystagmus" or twitching of the eyes of miners, which is produced by working in semi-darkness, the following interesting hypothetical experiment was proposed.

Imagine that you are in a cavern, the floor, walls and roof of which are absolutely devoid of color, and having surfaces of such a nature that they reflect no light; imagine that they are covered with some substance as lamp-black, only much blacker.

Put a lighted candle above your head, so that the light may fall in every direction, but not into your eyes. What can you see? Nothing but dead black.

Double your illumination, have two candles, and you will see "dead black." Then take a 20 candle-power lamp instead of the candles, and you will see nothing more than "dead black."

Try a searchlight, train it on the wall opposite, and imagine that a large black beetle, that has covered itself with the lamp-black-like substance, is crawling up the wall in front of you. You will not be able to see it.

It is impossible to distinguish one piece of "dead black" from another. It is evident that under such conditions increasing the light does not assist vision; it is simply wasting light.

Light, in the absence of all color, and in the absence of all reflections from surfaces, is useless for vision.

Now, imagine that you are in a brilliantly colored chamber—no matter how bright the colors may be—but that there is no light. What can you see? Again, nothing.

Color, therefore, in the absence of light, does not exist.

Now imagine that you are back in the cavern again, which is devoid of color but that the surfaces are crystalline, such as coal or jet, that is to say, they have innumerable small reflecting surfaces, or "surface brightness." With one lighted candle above your head, you will be conscious of black surfaces with innumerable specks of glistening white light.

This is the light that is reflected back directly into your eyes without diffusion, and represents one element in the "surface brightness" of the wall, and it can be measured.

Double the brightness of your sources, and you will get about double the amount of this surface brightness. Have four times the light and you get four times the brightness.

Let the beetle, now with a clean and glossy back, crawl up the wall again. You will be able to see a white spot of light moving, but you will not be able to recognize that it is a beetle

The conclusions to be drawn from this feat of imagination are: (1) that light, without color or surface brightness, is useless for vision; (2) that color, without light, does not exist; (3) that light without color, with surface brightness enables you to see a little.

In this connection it is interesting to consider what are the processes by which we become conscious of any existing object. Let us imagine what would take place in the brain of a child to whom any object, an orange, for example, was presented for the first time.

Every impression comes as a new one. The eyes are open but the images which have been carried to them have been vague and indistinct. They have not been differentiated. The sound of voices comes as a murmur or a noise, possibly broken by varia-

tions in intensity, as from the crash of a falling body, or the jangling of a bell; but the nicer discriminations of sound, which may be developed with increasing refinement until the most exact harmonies or the least discordant note is at once recognized, have not yet begun. The first impression conveyed to the eyes of the child after making the distinction between light and darkness would be that of color. When the orange was brought in his range of sight, its brilliancy would attract his notice and he would become conscious of a blotch of color, like the sunshine or the lamp-light which he has already seen, and this, in the sight center situated at the back of his brain, would occasion a flood of nervous energy, excited by the vibrations in the ether, and the neurons of the terminal nerve endings would respond with a quickened capacity to apprehend, to appreciate this same phenomenon when it again occurred. *It would be the beginning of those finer color distinctions that were to come later and which were to constitute the education of his color sense, which were to enable him to understand, to appreciate and to feel the beauties of the color harmonies of the world in which he lives.* Then gradually this splotch of color, otherwise so meaningless, would take on *form*, and he would realize that it was limited by a circle, and in gaining this knowledge a new group of cells would be energized, and another essential fact in relation to his surroundings would have been achieved. Then would come to him the realization of a new and more wonderful phenomenon: *the circle has depth*; and here an enormous advance has been made. He has been introduced into three dimensional space. Both sides of his brain are working synchronously. He has binocular vision. The image which has been made upon the retina of each eye has been carried to corresponding parts of the brain, overlapping and blending as in a stereoscope. A multitude of new impressions have been aroused, suggestions of the outer world, indeed of the universe, have been conveyed to him. His logical faculties have been awakened, and without either knowing or realizing it he has done the most *important* thing in the world. *He has begun to think.* The thought which he is unable to express has aroused his will, has excited his desire, has tempted him to experiment. He timidly and tentatively reaches out his hand and *touches* the thing that he has seen and

in recognizing the consciousness of its presence he has *done* the most *wonderful* thing in the world. He has established the existence of a problem, the solution of which has been the basis of the speculations or our most profound philosophers, from Plato to Kant. *He has located himself in space.* He has begun to find himself. He has commenced his education. He will now learn to differentiate between soft and hard, between rough and smooth, between elevation and depression, between those things which oppose and those which attract. With each new idea has come a new flood of energy, sweeping through his brain and making the pathway easier for those which are to follow. The skin of the orange is broken and the fragrance of the volatile oil is carried to his nose. It brings an odor like nothing else in the world, yet it is one of hundreds of perfumes and scents and smells that he is to learn to differentiate from all others, and with sensation comes *thought,* with *thought, suggestion,* and with suggestion *will,* and the motor influences which are to govern this will during all of his life have been established.

The orange drops from the baby hands and falls with a dull thump to the floor. It gives a sound that to the trained ear conveys intelligence of the nature of the thing itself. It is at once evident that that which has fallen is not metallic; it has not the flat sound of a closed book nor the overtones of a hollow wooden box. It is one of a thousand possible sounds and yet it carries a descriptive story to the listening ear and trained brain. Finally the fruit is retrieved, the skin is removed, the segments are broken apart, and everyone of these movements with the little sounds connected with them are educative. When at last a portion of the fruit is conveyed to the mouth they arouse,—who can say how many groups of motor influences: the whole body is moving, the neck bends, the arms, the wrist, the fingers, each with its separate centers in the brain represented by neurons, almost without number. When the segment is placed in the mouth the muscles of the lips, the tongue, the jaws, the cheeks—all are dominated by impulses which are sent out from the brain—and finally when the juice of the fruit is tasted and this wonderful complex of sensations has been united into what has been termed a sterognostic comprehension of the whole,

the entire brain has been excited into activity from front to back and from side to side giving instructions in co-ordination, in will, in logic, and perhaps in ethics. Each group of nerve centers that has been energized in receiving impressions or in sending out commands is being educated in the only way in which it can be to perform the work which it is ultimately destined to do.

So that not only the perception of form or color is an essentially psychic process but by the automatic relationships which are aroused through what are termed the association fibers in the brain, other emotions are excited, and what would seem to be a simple, becomes a most complicated process. The thing that we see may give rise to emotions far removed from that which might be naturally expected. For example, a landscape of most extraordinary beauty may be associated with some earlier circumstance of a repellent character and not only will that particular view be ever afterward disagreeable but things associated with that view of which we may be quite unconscious when they appear in other places and under other conditions may excite that same unpleasing sensation. It shows consequently that there can be no real or exact psychic values, for not only are the things which we see modified in our recognition of them by things which we *have* seen, frequently very early in life, but they may be so modified also by associated contigencies that there can be no exact and invariable value which is not modified by previous impressions. In consequence of this fact every view which meets the eyes is a composite of the thing seen with an additional modifying element which may be in some cases absolutely changed by the supplemental impressions which we bring to it. This has been so definitely recognized by the modern school of artists that they have long since realized that the more exact the reproduction of a landscape or of a face the less like is it to the original. It is impossible for any artist to place in his picture the fugitive impressions which are rapidly chasing each other over the features, or the flash in the eye which so illuminates the character, or the droop of the lip which may betray a weakness, and all of which are instantaneous. Monet painted seventeen views of a haystack because as the day changed, it was never twice alike. But if

he can suggest in vaguest outline that which he feels and sees he has made it possible for the understanding observer to supplement in his own mind that which has been suggested. The indefinite, hazy, shadowy, landscape then becomes vitalized by the associated memories which it has stimulated. With the definite, sharp-cut, precise reproduction of the actual form of the thing itself staring him in the face, as in a photographic representation of it, all of these subtler but therefore more real qualities which differentiate that thing from all other things in the world are masked. A mask not only conceals, it distracts the mind from that which is beneath it and prevents that play of the mind which enables one to build out of the shadowy semblance all of those beauties with which we would wish to see it invested.

All men of imagination, whether they are artists in stone or in words, whether they are the discoverers in science, the leaders in finance or the makers of an empire, are essentially and potentially poets and the poet is he who short-circuits truth through the fourth dimension of intuition.

We are all influenced emotionally by form and color. We unconsciously feel the depression produced by the black garments of widowhood, and the enlivening cheering effect of brightness and color. We feel the color atmosphere in which we live. They who live in a land of clouds reflect in their characters and bearing the shadows that fall upon them; while the sunshine glows in the lives, in the mentality, and in the activities, of those of southern lands. As the heavier and more massive forms of architecture have a morally depressing effect, as dark walls and sombre furniture drink in the light, as dim rooms and badly illuminated corridors are forbidding and foreboding, so is the converse true. So, too, the dazzling glare of brilliant lights brings out in actual detail all the sordid fittings of a poor room or the inharmonious settings of a badly furnished one. We feel instantly the atmosphere of the place we enter. The importance of beauty as an essential element in civic betterment and in its social aspects has not received the attention which it deserves. If we are influenced to the degree which I have indicated by our environment it must follow invariably that surroundings which give an atmosphere of quiet and which

pleasurably excite the imagination must have a beneficial moral effect upon the community. The atmosphere which exists to-day is one of excitement and the tendency is to increase this excitement by all forms of artificial stimulant. Our newspapers not satisfied with four-inch headlines in order to attract notice have adopted green and pink outer covers as an added appeal to the eye.

THE UTILITY OF ART.

The element of beauty in our common life has not only an esthetic value which in itself is important but there are certain by-products, if they might be so-called, which are incidentally developed and have even a greater bearing upon our lives.

In a mining district within an hour's journey from Pittsburgh a few years ago the homes of the miners were sordid and unkempt, the streets being littered and the back yards repositories for all sorts of rubbish. The corporation in charge of the community introduced in the management of the plant improvements in accordance with the most advanced methods, and among other measures prizes were offered for the best garden plots to be found about the homes of the workmen. This has resulted in an eager and intelligent competition and in place of an offense to the eye the town has become a beauty spot. Fences are lined with rows of hollyhocks and golden rod, the walks are bordered by attractive arrangements of garden flowers beautifully kept; vegetable gardens have become productive and in some instances have added to the annual income of the miners as much as $100. Miners working in dark coal shafts straining their eyes to see and having them dazzled by millions of reflections from the shiny surfaces suffer from an affection known as miners nystagmus, the rapid oscillation of the eyes, to which reference has already been made. I am told that the refreshing change from the gloom of the mine to the soft colors of the garden in which they work has already exercised a most beneficial influence upon this serious affection. In its moral effect in giving an appreciation of the values of better civic conditions in developing a civic spirit, interest has been aroused; they have not only made gardens they have made men and citizens.

The mental and moral effect of light and shadow, the difference

produced upon our state of mind by the glaring brilliancy of an unshaded Welsbach light, especially an old one, or the soft glow of an even yellow illumination is felt by every one although by no means always recognized as a cause of nervous irritation. In some of the most persistent cases of eyestrain after the ophthalmologist has employed the highest degree of skill in determining the correct combination of lenses to be employed it will be found that the discomfort is due to a badly placed lamp, to the improper use or absence of shades, to an insufficiency or an excess of light, to some specular reflection, or other local fault in the illumination about which he has not been advised.

There is probably no one simple element that more deeply concerns the welfare of all people than correct lighting.

In the studies in efficiency in lighting we seem to have forgotten the beauty of light itself. No mere luminosity will replace a visible light source. By grouping lights of low power and properly planning them—using translucent, frosted, or prismatic globes, effects of great beauty may be secured. It would seem unnecessary to put emphasis too strongly on the superiority of indirect illumination.

It is in the dark streets and unlighted alleys that crime skulks. Good lights are cheaper than policemen and more effective. When the dark corners are lighted we are ashamed to have them cumbered with debris and we clean them up.

When a man comes home after a hard day's work, stumbles through a dark hallway and finds the living room dimly lighted by an unshaded lamp with a smoky chimney, glaring, yet insufficient, bringing out all of the misery without softening any of its harsher outlines, is it to be wondered that he makes his stay as short as possible, seeking in preference the brightly lighted saloon where appeal is made to his eyes as well as to his appetite? Until we make the homes of the poor fit habitations for them to live in we cannot expect them to spend much time in them, nor can we expect to make good citizens out of them. How can we hope for civic pride or civic righteousness to come out of an unlovely dirty tenement house. A stream will not rise higher than its source, and the source is the home and the family.

One of the easiest, one of the least expensive methods of mak-

ing the poor home livable would be to introduce good lights in it. Could a more effective or a more helpful propaganda be inaugurated than to teach the poor to light their homes adequately, beautifully and cheaply? This could be done with a minimum of effort, for many of the homes are lighted imperfectly, in an ugly way and at an extravagant cost. It should be one of the first steps in the new movement for the conservation of vision.

It ought not to be a difficult matter to secure proper lighting for our public institutions. Of all buildings those which should demand good lighting are our public libraries. Still to-day when so much has been accomplished on these lines, it is the exception rather than the rule to find a public library in which the lighting is not atrocious.

IMPORTANCE OF GOOD LIGHTING.

The importance of good lighting in public buildings is so self-evident that it would not require mention were it not for the fact that often in the finest specimens of modern architecture this seems to have been overlooked.

Some time since I happened to be in one of the progressive western cities where the State house, a splendidly located edifice on a hill, which was notable for its beautiful approaches, was so poorly lighted that on entering the relatively small doorway on a clear sunshiny morning it was found that the entire main floor was artificially illuminated and the basement floor in which were situated some of the most important offices for the transaction of the business of the state could not have been used were it not for the artificial lights employed. Unhappily this is not an exceptional circumstance, alike serious defect is found in the multi-million dollar State Capitol at Albany, N. Y.

In our auditoriums the lights, to paraphrase the meaning of the apt French expression, "jump to the eye." In unnumbered public schools to-day, in which artificial lights must be used, the children are facing flickering gas lights in a vain attempt to see the marks on shiny black-boards. The school authorities have not yet learned that dark red and green walls absorb the light for which the children are suffering.

The time has fully arrived when an authoritative body composed of architects, of illuminating engineers, of school-men, of

ophthalmologists and of all others who have to do with the management of light or the use of the eyes should collaborate in the development of authoritative plans for the education of the public on sight protection. The American Medical Association is now forming a sub-committee from the medical societies in every state in the Union on the conservation of vision. The National Education Associaton is deeply interested and is now ready to support any proper effort for broader instruction on the care of the eyes.

It was proposed several years ago that there might be one day in the year given to the conservation of sight. It would be of great interest for the children to study the condition of their own schools. In this respect their essays might include the physics of light, illumination, natural and artificial, the amount of window space necessary for a well lighted room, how it should be placed, in a word the hygiene of the eyes. The study which this would necessitate would give a groundwork of knowledge which would promote better conditions in the future than exist at present. It would constitute a practical lesson on one of the essentials of right living and would result in collateral benefits of inestimable importance.

DISCUSSION.

Mr. G. H. Stickney: I can not pretend to discuss this paper. On the other hand, I feel that we must express a special appreciation for it. It seems to me that it is one of the most valuable papers that I have listened to in a very long time. To those of us especially who work largely from the engineering end it brings a point of view which should modify our thought, and round out our practise.

Dr. H. E. Ives: Mr. President, I wish to second, if I may so put it, the remarks of Mr. Stickney. I think that it would be safe to say that we have never in our history had presented to us so clearly and impressively the importance, the almost sublime importance, of illuminating engineering. We have had pointed out to us among other things the importance of association. We are accustomed to a certain kind of lighting and are apt to argue because we have been adapting to that kind of

lighting through the ages that it is necessarily best. But after all much of it may be a question of association. I talked not long ago with a prominent member of this Society, who told me that the people of his house had become entirely adapted to another system of illumination than the one to which they were formerly accustomed although the new system at first seemed all wrong. It opened my eyes to the fact that if the associations are properly planned it may be that we can very easily improve upon daylight, or anything else that you want to present as ideal. It gives us an opportunity. For instance, we can light a room by light from the side or light from overhead, and we can adapt ourselves to either one. We can allow ourselves to be guided by other considerations than first impressions. We can search out new lighting effects.

Dr. Lewis has spoken of the healthful effect of proper associations and proper lighting conditions. Has it ever occurred to you that we might start a new school of medicine. We have all sorts of "paths" who have been in a correspondence school for six weeks and learned all there is to be learned about healing. May we not look forward to the "photopath" who will put a patient in a calm, restful room, and subject him to lighting effects to subdue or stimulate him until his nervous condition improves?

Another point which Dr. Lewis has made which I think is of very material commercial importance is that the matter of lighting is getting to be recognized as an aid to architecture. Formerly an architect designed his building as it would appear in daylight. Then the lighting was put in as a necessary evil—and it usually was an evil. Now, due to the application of a great many minds—and very artistic minds—to the lighting problem, we see to-day lighting installations which are appropriate. So that, speaking for myself, I would prefer very often to see the room lighted up by night rather than to see it by day, simply from the beauty of the light sources.

As I said before, we ought to be guided by the paper brought before us by Dr. Lewis to realize the real solemnity of the subject that we are handling.

NEON TUBE LIGHTING.*

BY GEORGES CLAUDE.

It is known that the discovery of the rare gases,—those very curious gases which were contained in the atmosphere unknown to us—is the magnificent work of Sir W. Ramsay. •It is known also that it was the distillation of liquified air which led Ramsay to the securing of such wonderful results, results which are all the more marvelous since they were obtained with a modest apparatus producing from 1 to 2 liters of liquified air per hour.

I had imagined that by using the much greater facilities at my disposal and with the use of apparatus which can liquify 10,000 cubic meters of air per day, I might have obtained some new results. But alas, I found that there was nothing to do after Ramsay.

But if in spite of my desires, I have been unable to add to the list of rare gases, I have nevertheless been able to produce them, especially so in the case of the neon, in far larger quantities. Things are so arranged in my oxygen apparatus that this neon is the residue of the progressive liquefaction of air, and is obtained as a by-product of the industrial manufacturing of oxygen. The output of this apparatus is so large, that in spite of the insignificant proportion of neon in the air, 1 part to 66,000, yet with a modest apparatus of 50 cubic meters of oxygen per hour, 100 liters of neon can be produced in a day. Balloons can be filled with this gas as I am showing it to you here, and balloons that can fly, as the density of neon is two-third times that of air.

Consequently, neon being such an abundant industrial product, I have engaged myself in a search for uses for it.

I have directed my efforts toward light production. I do not have to tell you, gentlemen, what a serious drawback the ever increasing, dazzling and blinding properties of modern lighting possess. And you are all aware of the hopes that have been en-

* Outline of a lecture given at the seventh annual convention of the Illuminating Engineering Society, Pittsburgh, Pa., September 22-26, 1913.

tertained for the uses of diffused lighting without any fatigue to the eyesight and which might be secured from the marvelous and fine brightness with which the rarefied atmosphere in the Geissler tubes is illuminated. Unfortunately, these last have remained up to now detestable apparatuses, since the luminescent properties of ordinary gases are not very good. Nitrogen, is the only gas used, thanks to the remarkable perseverance of Moore, although the efficiency of his apparatus is very low—1.7 to 2 watts per candle.

Rare gases are remarkable for their ability to become luminescent; their spectra are remarkable; the one of neon is especially so. It contains some numerous and superb lines of red, orange and yellow, and three important lines of green. Unfortunately, it contains neither white nor violet tints. Certainly, this absence of blue is a big fault so far as a source of lighting is concerned; but I supposed it possible to correct this fault, and I have passed on to something else.

I had in view other reasons, besides the richness, of its spectrum, to be taken up in a study of neon. First, neon really possesses an extraordinary aptitude to become luminous. It is a long time since the illustrious Sir. J. Dewar has succeeded in the production of tubes with neon which are illuminated spontaneously at the points of maximum amplitudes of Hertz' interferences and which are extinguished at the nodes. So that these peculiar detectors furnish very original means with which to measure the length of the waves in the installations of wireless telegraphy.

And it was another one of Ramsay's colleagues, Professor Collie, who with the neon that I had sent to Ramsay, has been able to make the following observation, a very important one indeed: with a sealed glass tube containing a little quicksilver in a rarefied atmosphere of neon, if one shakes the tube in a dark place, the mercury looks like a real rain of fire. This curious phenomenon is explained by the result of Bouty's experiences. This scientist has indeed been able to observe with great surprise that neon is easily passed through by an electric discharge: where it is necessary to have 1,000 volts, for instance, in the case of air, but 13 volts are sufficient with neon; and you can then appre-

ciate Collie's phenomenon: the electrifying of the tube by the shaking of the quicksilver is enough to cause discharges in the gas.

With such properties, neon can very well enter the field of production of luminescence. I have therefore, directed my efforts toward using this gas in immense Geissler tubes, similar to the Moore tubes. The first obstacle encountered was indeed a queer one. You know, gentlemen, that there is also another name for rare gases—*noble gases*. Now, it would appear that neon entertains a very lofty idea of its dignity; it is quite capable of working wonders by itself; it absolutely refuses to perform anything when it finds itself in contact with those inferior fellows known for instance as hydrogen or nitrogen. When it is remembered that these gases are much more inferior than it, either in their aptitude for luminescence or with respect to luminous efficiency, even minute traces of them mixed with neon are sufficient to displease it to such an extent that none of the lines of its spectrum are visible in the light produced. Here is a tube which has 99 per cent. of neon and 1 per cent. of nitrogen. Only the light produced by the latter appears.

It is not enough, therefore, to introduce into the luminescent tube absolutely pure neon, for if at the start the tube shines with a magnificent brightness, the impurities emitted by the electrodes when the current is passing through, cause very rapidly the drop of its luminescence. In order to overcome this serious difficulty, I was compelled to devise a process which would purify the neon in the tube itself, as fast as the impurities were introduced into it by the passage of the current. I was led with this object in view, to make use of one of the curious resources of liquified air; the remarkable property discovered by Dewar that charcoal absorbs air with great energy when frozen to the temperature of liquified air.

But it is under peculiar conditions that I use this property. Charcoal does not mingle indifferently with every and all gases. Generally speaking the harder they are to liquify the harder it is to absorb them; this absorption is very much smaller in the case of neon than with the different sorts of gases which might accompany it. And you can then conceive easily the process which I

have devised in order to purify the atmosphere of my neon tubes. The tube to be filled is connected to a charcoal receiver, immersed in liquified air. This charcoal slowly absorbs the gases developed through the passage of the current, but it leaves the neon. By this contrivance a pump has been made; but this is an intelligent pump which sucks and carries away the troublesome molecules, and respects the others. After a laborious process which lasts for many hours, the neon remains victorious; the tube is finished, sealed off from the charcoal receiver, and will show thereafter without weakening the superb light of the neon. Superb! well all tastes are different and you will perhaps find that I exaggerate; but I shall try just now to give you a more complete satisfaction.

This difficulty having been overcome, another one cropped up. I had noticed that the neon tubes thus obtained were short-lived. After showing a rapid increase in the difference of potential at the bars, they began to flicker and to crackle, and lastly went out in 5 or 6 hours. Well, gentlemen, you will easily recognize there the strange phenomenon discovered by Moore. Moore has observed indeed that the atmosphere inside of his tubes was rarefying itself progressively and that finally the tubes went out entirely; this fact, a very mysterious one indeed, had neutralized his efforts up to the moment when he had the idea of introducing nitrogen in his tubes, by means of an ingenious electromagnetic valve, as fast as the rarefaction took place.

Unfortunately, such a remedy could not be applied in the case of neon for if Moore's observations are accurate, the quantity of nitrogen absorbed by his tubes is astonishing: 200 liters per year for a tube of 50 m. If my neon tubes were such gluttons, my apparatus of liquified air would be inadequate to meet their demand. It was of course necessary for me to look for conditions which would permit me not to consider the absorption of neon, so that one charge, one single dose of neon, could insure to the tube a very long life, one comparable to that of an incandescent lamp.

To attain this result, it was necessary to begin by determining the manner of this absorption. I was able to observe at the outset that the electrodes of the first tubes, which were very

small, became incandescent upon the passage of the current and volatilized rapidly. A metallic deposit used to form from these scales and strips in the neighborhood of the electrodes. I have thought that it was this metallic deposit which on forming absorbed the neon. And in fact, by dissolving these deposits in nitric acid, gases were developed containing neon.

Therefore, there is no doubt that the volatilization of the electrodes is what makes the trouble. In order to minimize it, the use of large electrodes will be necessary henceforth, which can be very little volatilized by the current. Experience has confirmed this supposition and to such an extent that by using electrodes of 5 sq. dm. per ampere the volatilization is rendered nil and the life of the tubes lengthened considerably.

The life increases naturally with the length of the tubes, as there are always only two electrodes to absorb the neon, and that the longer the tube the more neon it contains. With tubes 6 m. long, you can attain easily 1,000 or 1,200 hours, and I have tubes of 20 m. in excellent condition after 2,000 hours. This is superior to the incandescent lamps.

Here is the problem solved then, and solved in a manner unexpectedly simple. We are in possession of tubes capable of showing the spectrum of neon in all its purity. These tubes, which are not provided with valves, are much more simple than those previously made, and give an entirely satisfactory length of life.

What advantages have these tubes as compared with the nitrogen tubes? Gentlemen, I shall only insist upon the essential points and any one desiring further details is referred to the paper which I read before the Société des Electriciens, November 8, 1911.

At the outset the necessary difference of potentials is three times less than with nitrogen; this is a great advantage with respect to safety. These 6 m. tubes have less than 800 volts at their ends. Three could be mounted upon a transformer of 3,500 volts.

Secondly, its illuminating power is higher, 200 candles per meter instead of 60. You can consequently use for lighting tubes which are much shorter and accordingly less expensive. Another

advantage to be derived is that these tubes can be manufactured in factories and carried all ready for use to a customer or client.

And lastly—this is the most important part—the illuminating efficiency is much greater. Instead of 1.7 watt per candle obtained by the use of nitrogen, only 0.5 is required for the long neon tubes. May be you do not consider this marvelous when you make a comparison with arc lights; but it has to be borne in mind that the question is one of spheric and not hemispheric watts. Furthermore, no expensive carbons are required and all upkeep charges are done away with. Really, when everything is considered, I believe that with the exception of the mercury lamps, the neon tubes supply the most economical lighting.

In some interesting experiments carried out at the Laboratoire Central d'Electricité, Messrs. Broca and Laporte have observed that the neon light is physiologically excellent on account of its dull luminescence and that it increases visual acuity by 25 per cent. You can really notice with what clearness and sharpness the small figures on the reports which I am passing around can be seen.

All is rather perfect therefore but for the color, which is another matter. Evidently this light is too red; it is too red because of its want of blue. Look at this bouquet; it is of a beautiful blue; see how dull and disappointing it is. On the contrary here are some poppies: see how resplendent they appear. No doubt, this predominance of the red color allows of some beautiful illuminating effects. Here you have as an instance, the Grand Palais at the Champs Elysees, in Paris, lighted by neon in 1910 on the occasion of the automobile show held then; and the St. Ouen Church of Rouen which was lighted by 50 neon tubes during the festival of the Norman millenium. Undoubtedly, in a number of cases of industrial lighting this light could be applied in preference to that of mercury light, since it is very economical. Allow me indeed to insist and to bring to your notice with what strange facility you have accustomed yourselves to such a red light, so as to retain only a pleasantly warm impression of a golden yellow from which the red is completely absent.

But I have to admit that this excess of red is hardly acceptable in the majority of cases and I have applied myself to having

this light corrected. There is a solution which seems to me plain and that is to combine the pale mercury light with that of the bright neon. In this case, however, there are two difficulties to be overcome. The first is that mercury and neon when placed in the same tube will not blend and work together; second is that, if it be required to mingle blue tubes with red tubes, the Cooper-Hewitt mercury-vapor tubes would require a continuous current at a low tension, whereas the neon tubes demand alternating current at high tension. These do not go together. I have, however, made correcting tubes, which are similar to the ordinary neon tubes but having a little mercury. These tubes light with the alternating current as in the case of usual neon tubes; but mercury volatilizes progressively and the blue light which mercury gives, invades the whole tube.

Well, here is progress, to be sure. Our blue bouquet has recovered its colors, but it is our poppy bouquet which now looks pitiable; and as to ourselves, gentlemen, instead of being rubicund, we are now just ghastly pale.

Patience! I light this neon tube and here we have the sun's light succeeding to that of the moon's pale light. See how everything has returned to its normal state; the blue color of this bouquet, the red of that one, the delicate hues of those flowers so varied; and above all you have noticed, ladies, how your complexion matches nicely with this light. And what interesting ornamental effects can be obtained by the combination of tubes of different colors. Here is an example, a fixture put up by the firm of Paz & Silva for the automobile show in Paris.

The efficiency of these correcting mercury tubes is, unfortunately, notably inferior to that of the neon tubes and should be in the near neighborhood of 1 watt per candle. It is acceptable even at that. Having an equal number of blue and red tubes, you will see that a very pleasant light is obtained, very much diffused, without shadows and at an energy consumption of 0.8 watt per candle. This is better than what has hitherto been obtained with luminescent lighting.

Gentlemen, I have another application to bring to your notice. If the objectionable red features in this light cannot be always neutralized, there are cases where it proves to be an unquestion-

able advantage. To begin with, for illumination of monuments, as I have already remarked; but it is of inestimable value for advertising illumination, where the more dazzling the light is, the more it will strike the eye, and hence the better it will be. Now, with neon you are liberally served.

I have been able to make with the aid of my collaborator, M. de Beaufort, some tubes of a small diameter which can be bent, or twisted without difficulty and be given any desired form, and be lighted with red or blue lights. There might be some apprehension that the minute quantity of neon contained in those tubes might give them only a short life. However, I had the pleasant surprise of finding out that with the sole condition respecting the rule of the feeble density of the current at the electrodes, these small tubes lasted as long as the big ones. Here is a tube which has burned 1,400 hours. This one operates at the rate of 30 milli-amperes, sufficient as you can see, to give to it a very luminous aspect.

These small apparatuses work on a common transformer with alternating current. Upon continuous current, the transformer is controlled by a rotating or Wehnelt interrupter. The cost of an installation is not much higher than that of ordinary apparatus and the consumption of energy is less and affords a much better effect. There is certainly to be found here a brand new method for the industry of luminous advertising.

THE ILLUMINATING ENGINEERING LABORATORY OF THE GENERAL ELECTRIC COMPANY.*

BY S. L. E. ROSE.

Synopsis: About the year 1895 the General Electric Company started at the Lynn works the study of illumination problems and the proper application of arc lamps. In 1909, the department was moved from Lynn to Schenectady. The present laboratory is equipped for making tests on all kinds of illuminants. The work of the laboratory is divided into four main divisions: namely; commercial investigations and their applications, photometric testing and developmental, research, and photographic. Facilities are available for a thorough investigation of all means and methods of artificial illumination and the testing of lighting units for commercial or special work. Parts of the laboratory equipment are described and illustrated in this paper.

Before giving a description of this illuminating engineering laboratory and the work being carried on there, perhaps a review of its growth from its inception to its present proportions will be of interest.

About the year 1895, the General Electric Company started at its Lynn Works the study of illumination problems and the proper application of arc lamps. This was the beginning of what is now known as the illuminating engineering laboratory and the work was carried on under the direction of Mr. W. D'A. Ryan who is director of the present laboratory. The first photometer room occupied a floor space of about 500 square feet (38.09 sq. m.). The photometer was of the single-mirror crane type and could be used as a constant length, constant intensity or constant radius photometer. All photometric testing was done on this one photometer and it was a number of years before more space was devoted to this work.

In the fall of 1907, three rooms, with an aggregate floor space of approximately 1,500 square feet (114.27 sq. m.), were built in a new factory building and three photometers installed, one for small units, one for large units and one for miscellaneous work.

* A paper read at the seventh annual convention of the Illuminating Engineering Society, Pittsburgh, Pa., September 22-26, 1913.

In 1909 the illuminating engineering department was moved from Lynn to Schenectady. None of the photometers was moved from Lynn and the ones now in use at Schenectady were designed, built and installed under the supervision of the department. A description of the photometers used at Lynn and the ones in use at Schenectady for large unit work as well as the methods of test have been given in a previous paper before this society.[1]

The present laboratory is situated in a two-story brick building with an aggregate floor space of approximately 7,000 square feet (533.27 sq. m.). (See Fig. 1.)

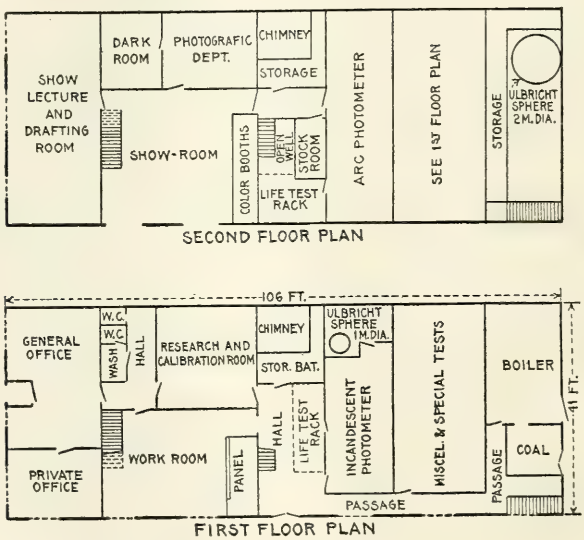

Fig. 1.—Plan of laboratory.

Two universal rotators and a single-mirror crane type photometer (Fig. 2) are available for obtaining candle-power distribution curves of small units. The latter photometer is very easily changed into a constant length, constant intensity or constant radius photometer. It is mostly used as a constant radius photometer and the radius of test may be changed at will from 5 feet (1.524 m.) to 20 feet (6.096 m.) or any intermediate point according to the size of the unit being tested. For convenience of cal-

[1] I. E. S. TRANS., page 641, vol. 6, 1911.

culation, all tests, so far as possible, are made at a radius of 10 feet (3.04 m.). A sector disk is employed to increase the range of the photometer, when necessary. For obtaining total flux on small units, absorption of small units, globes or balls, an Ulbright sphere of 1 meter diameter is used and for large units an Ulbright sphere of 2 meters diameter is employed. In addition to the regular photometers mentioned above, a number of portable photometers, of both foreign and domestic make, are available for outside tests and for special work in the laboratory. For spectrum analysis, color absorption, research and special investigations, a spectrophotometer, spectrometer and colorimeter are available.

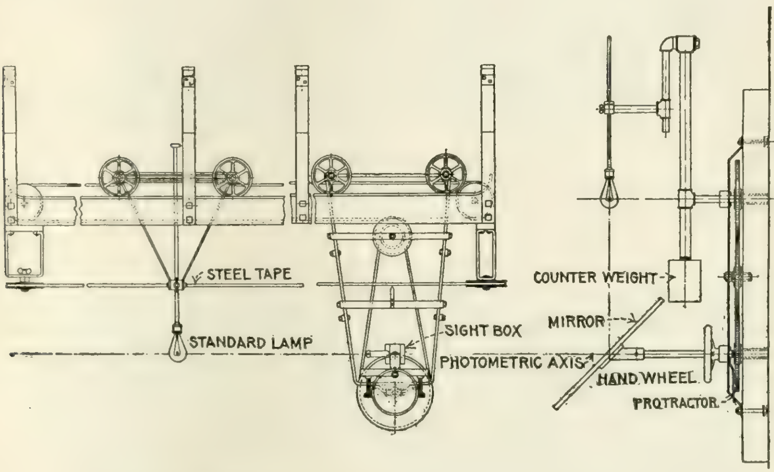

Fig. 2.--Single-mirror crane type photometer for small light units.

Energy for lighting, power and experimental purposes is available from the direct current three-wire shop circuit of the General Electric Company, the alternating current three-wire commercial city circuit, a motor driven alternator which can be arranged to give 25 to 60-cycle current, two motor driven direct current generators of 500 to 700 volts and 125 volts respectively, and a constant current transformer for alternating current series work. A switchboard panel is so arranged that current from any of the above sources may be switched on any circuit in the building. In addition to this, a circuit leads to each room from a 60-cell storage

battery. This battery is primarily for furnishing energy for incandescent unit work and working standard lamps, but may be used as an emergency supply, if necessary.

For the testing of gas units, the laboratory is equipped for both high and low pressure work. For measuring consumption, wet test meters are available which will operate on pressures from 2 to 3 inches (5.08 cm. to 7.62 cm.) of water up to 10 pounds (4.53 kilograms) per square inch (6.45 sq. cm.). A motor driven compressor is installed which will take gas from the city mains and deliver it at pressures ranging from 2 or 3 inches (5.08 or 7.62 cm.) of water up to 10 pounds (4.53 kilograms) per square inch (6.45 sq. cm.). Indicating and recording pressure gauges, an indicating gravitometer and a recording calorimeter complete the equipment. (Fig. 3.)

The work of the laboratory is divided into four main divisions, namely: commercial investigations and applications, photometric testing and developmental, research and photographic. The whole comprises a thorough investigation of all means and methods of artificial illumination and testing of lighting units for commercial or special work.

The commercial division is constantly giving advice and furnishing lighting recommendations to all parts of the world and for all classes of lighting of which the following may be mentioned as an illustration of the diversified character of the work; the office building of the Buffalo General Electric Company,[2] the Panama Canal, and the Panama-Pacific International Exposition to be held in San Francisco in 1915. In connection with the commercial division, a display of various types of lighting units is maintained together with intensity and color booths (Fig. 4). The latter two are probably the demonstrations of greatest interest to the public. The terms used by the expert in the art of illuminating engineering often seems, to the layman, vague and inexpressive. The merchant may be told, by the engineer, that he requires for proper illumination of different departments of his store, 2, 5, 7 or 10 foot-candles, but owing to the vagueness of his conception of the foot-candle, he is still necessarily "in the dark," as to the amount of illumination he is contracting to buy.

[2] For full description see I. E. S. TRANS., vol. VII, page 597, 1912.

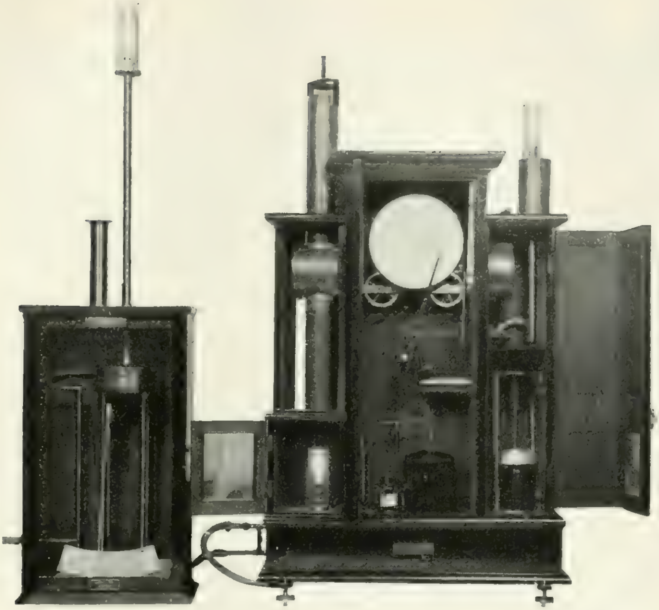

Fig. 3.—Gravitometer and calorgraph.

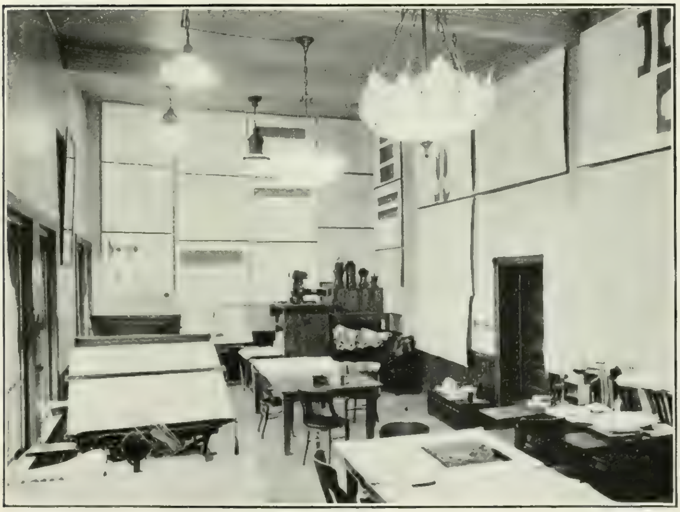

Fig. 4.—Demonstration room.

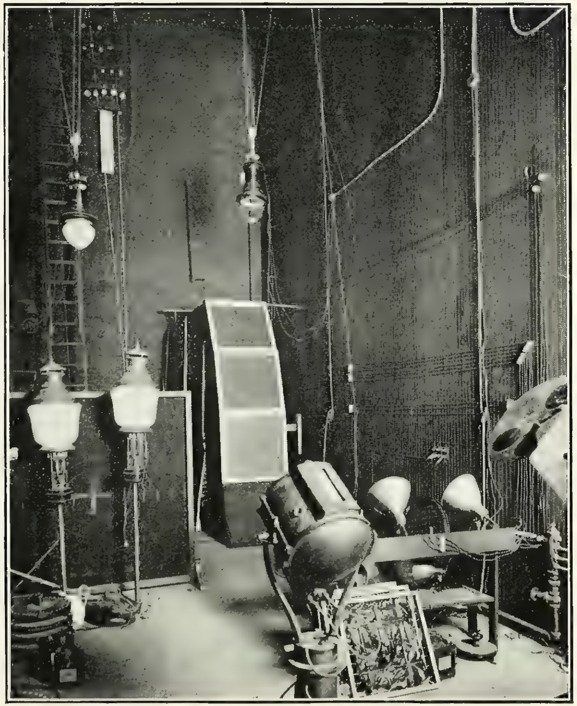

Fig. 6.—A view of the constant radius room.

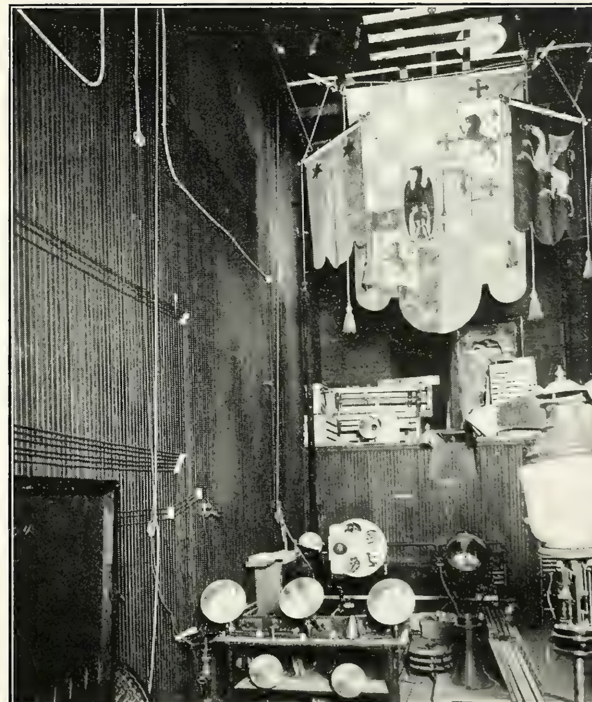

Fig. 5.—Constant radius room, showing shield for five-light standard.

The idea of the intensity booths is to show the intensity of illumination in steps of ¼, ½, 1, 3, 5, 7½, 10, 15 and 20 foot-candles. This demonstration is made in a row of booths extending along one side of a room, each booth measuring approximately 2 ft. by 3 ft. 6 in. (0.61 × 1.07 m.). By the manipulation of switches, these same booths are used to demonstrate the difference in color of the ordinary illuminants now in use and daylight.

The photometric division furnishes illumination data to all the other divisions, outside departments, sales offices and through them to the general public. Thorough tests are made on all kinds of lamps and lighting equipment. Street lighting and interior systems are tested under operating conditions. Experimental tests are carried on night and day when necessary to try out some new piece of apparatus for the patent department, or furnish special data to the engineers of the laboratory. New designs of lighting apparatus and systems are constantly being devised, constructed and tried out to determine their commercial value or their application to some special purpose. (See Fig. 6.)

The research division carries on special investigations of a scientific nature.

The photographic division furnishes the commercial division as well as the sales offices, architects, engineers, etc., with day and night views of representative installations as well as many conditions illustrating problems which are encountered and examples of both good and bad lighting.

The purpose of the laboratory is utilitarian and altruistic and it is devoted to the services of producers and consumers of artificial light and to the betterment of the art of illumination.

TRANSACTIONS
OF THE
Illuminating Engineering Society

Published monthly, except during July, August, and September, by the
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GENERAL OFFICES: 29 WEST THIRTY-NINTH STREET, NEW YORK

VOL. VIII NOVEMBER, 1913 No. 8

Council Notes.

A meeting of the Council was held in the general offices of the society, 29 West 39th Street, New York, November 14, 1913. Those present were: C. O. Bond, president; Joseph D. Israel, general secretary; V. R. Lansingh, C. A. Littlefield, L. B. Marks, treasurer; Preston S. Millar, C. J. Russell, F. J. Rutledge, W. J. Serrill and G. H. Stickney.

The meeting was called to order at 10:30 A. M. by President C. O. Bond.

The minutes of the October meeting were adopted.

Mr. C. A. Littlefield, chairman of the Finance Committee, reported that his committee had approved vouchers Nos. 1476 to 1512 inclusive, aggregating $1,646.25. Payment of these vouchers was authorized. The committee also recommended an appropriation of $100 as the quota of the society towards the expenses of an International Commission on Illumination. The appropriation was granted. Mr. Littlefield, also reported that the Finance Committee would submit at the December Council meeting a budget for the present administration.

A report on the accounts of the society for the year of January 1 to September 30, 1913, which had been prepared by a certified public accountant, at the request of the Finance Committee of the previous administration, was received. The report will be published in the TRANSACTIONS. The earnings for that period amounted to $8,256.49; while the expenses, including an estimate of outstanding debts, aggregated $8,175.65.

Mr. Israel reported that the total membership of the society, counting the resignations and applications presented at the meeting was 1,392, and that the expenditures for the first month of the present fiscal year had aggregated $2,893.17. The receipts during that period amounted to $291.22.

The following amended report of the Council Executive Committee, covering business transacted by the committee since the previous Council meeting, was adopted:

A meeting of the Council Executive Committee was held in the general offices of the society, October 31, 1913. Those present were Chas. O. Bond, president; Joseph D. Israel, general secretary; C. A. Littlefield, L. B. Marks, treasurer, and Preston S. Millar.

Mr. Preston S. Millar was appointed chairman of a Committee on Education of the Illuminating Engineering Society. The former name of this committee was Committee on Collegiate Education. It was suggested that among other things the committee be asked to consider the preparation of a tentative course in illuminating engineering for schools and colleges.

Mr. C. E. Clewell was appointed chairman of a sub-committee on Office Lighting of the Committee on Popular Lectures. An appropriation of $25 was granted for stenographic expenses in connection with the work of the sub-committee.

The following additional committee appointments were made: Finance: A. Hertz, W. J. Serrill; Section Development: Joseph Langan; Membership: C. J. Ramsburg; Board of Examiners: W. Cullen Morris, chairman, and C. H. Sharp; Editing and Publication: Clayton H. Sharp, chairman; A. S. McAllister, W. J. Serrill.

Twelve applicants were elected members. Their names appear on another page.

Ten resignations were accepted.

The following report pertaining to the society's policy in supplying copies of papers to authors was received and adopted:

Your Committee, appointed to reconsider the policy of the society in supplying authors with copies of their papers which are presented before meetings of the society, begs leave to submit the following recommendations:

When a paper is printed in advance, twenty-five (25) copies shall be sent to the author.

When an author furnishes to the general office the names and addresses of ten (10) or less, non-members of the society, to whom he desires to have copies of his paper sent, the general office will, if copies are available, mail to each of these persons a copy of the TRANSACTIONS containing the paper in question, indicating at whose request it is sent.

That the standard form of reprint be changed to secure minimum cost compatible with good appearance; the pagination of the paper, as printed in the TRANSACTIONS, being considered satisfactory. This will not preclude the issuing of more expensive reprints when so ordered.

That a suitable notice disclaiming responsibility of the society for statements or opinions of authors be printed on the title page of all papers, whether in the TRANSACTIONS, advance copies or reprints.

Respectfully submitted,
HERBERT E. IVES,
C. H. SHARP,
G. H. STICKNEY, Chairman.

The report was adopted and a vote of thanks extended to the committee.

In accordance with a recommendation in the foregoing report it was voted to place the following statement on all papers of the society:

The Illuminating Engineering Society is not responsible for the statements and opinions advanced by contributors.

Mr. V. R. Lansingh reported verbally on the progress of the work of his Committee on Sustaining Membership.

Reports on section activities during the past month were received from the following vice-presidents: Mr. G. H. Stickney representing New York, Mr. W. J. Serrill representing Philadelphia and Mr. J. W. Cowles representing New England.

Mr. Israel reported on the activities of the Pittsburgh and Chicago Sections.

The following appointments to committees were confirmed: Nomenclature and Standards, A. E. Kennelly, chairman; Research, H. E. Ives, chairman; Advertising, R. E. Campbell; Papers, E. J. Edwards, George S. Barrows, H. A. Hornor, C. E. Stephens, M. G. Lloyd, Alexander Duane; Reciprocal Relations, W. J. Serrill, chairman; Progress, T. J. Litle, Jr., E. L. Elliott, T. W. Roth, W. E. Wickenden, H. S. Hower, Wendell Reber; Glare from Reflecting Surfaces, F. A. Vaughn, N. M. Black, J. R. Cravath, F. H. Gilpin, M. G. Lloyd; Lighting Legislation, Ellice M. Alger, Oscar H. Fogg, Herbert E. Ives, Clarence L. Law, F. J. Miller, G. H. Stickney, L. A. Tanzer, W. H. Tolman.

It was resolved that the Council of the Illuminating Engineering Society extend a vote of thanks to Mr. Joseph B. Gregg for his valuable assistance in arbitrating an account presented by the Hill Publishing Company.

Informal mention was made of a recent movement started in the West to organize a San Francisco or a Pacific Coast Section of the society.

The meeting was adjourned at 1:15 P. M.

Section Notes.

CHICAGO SECTION

A meeting of the Board of Managers was held in the Grand Pacific Hotel, November 5. Those present were: Dr. M. G. Lloyd, chairman; J. B. Jackson, secretary; J. R. Cravath, M. J. Sturm, and H. B. Wheeler. After considerable discussion of a program for the present year, it was decided that it was not desirable to arrange a definite program for the full year, on account of the arrangement of a number of joint meetings with other societies, the dates of which could not be determined at the present. Mr. Sturm was delegated to arrange a joint meeting with the Chicago Architectural Business Men's Association for January.

A meeting of the Chicago Section was held in the Auditorium of the Western Society of Engineers, Monadnock Block, Chicago, November 12. A paper entitled "The Illumination of Street Railway Cars" was presented by Messrs. L. C. Porter and V. L. Staley of the General Electric Co. An excellent exhibit of reflectors, holders, fittings and accessories was arranged by the Exhibition Committee, of which Mr. H. B. Wheeler is chairman. Mr. W. A. Durgin, Assistant Chief Testing Engineer of the Commonwealth Edison Company, gave the first of a series of 20 minute talks on the "Fundamentals of Illumination." Sixty-four members and guests attended the meeting.

The December meeting is to be held at the residence of Mr. W. A. D. Curtis, when a paper entitled "The Lighting of the Home" will be discussed.

In January, there will be a joint meeting with the Chicago Architectural Business Men's Association, at which Mr. J. B. Jackson, secretary of the Chicago Section, will give a paper entitled "Planning Lighting Installations."

NEW ENGLAND SECTION

A meeting of the Board of Managers of the New England Section was held in the Hotel Georgian, November 3. Those present were: C. A. B. Halvorson, chairman; C. M. Cole, secretary; J. W. Cowles, vice-president; R. B. Hussey, J. M. Riley and R. C. Ware.

The meeting was devoted to the consideration of a program of meetings for the present year. A campaign is to be undertaken to increase the membership of the section.

NEW YORK SECTION

A meeting of the Board of Managers was held November 15, in the general office of the society, 29 West 39th Street, New York City. Those present were: W. C. Morris, chairman; G. H. Stickney, vice-president; O. H. Fogg, W. H. Spencer, H. B. McLean, M. D. McDonald, H. B. Rogers, S. W. Van Rensselaer, and C. L. Law, secretary. The meetings' program for the rest of the year was discussed. Arrangements have been made for a number of excellent papers and joint meetings with other societies.

The New York Section held a joint meeting with the New York Companies' Section of the National Electric Light Association in the Auditorium of the New York Edison Company, November 17. Mr. S. G. Rhodes of the New York Edison Company gave a talk on "Street Lighting Abroad." Mr. H. W. Jackson of the General Electric Company gave a lecture on the latest improvements in incandescent lamps. Mr. Alexander Maxwell of the New York Edison Company exhibited several Neon tube lamps. About 125 members of both organizations were present.

PHILADELPHIA SECTION

On November 20, a joint meeting of the Philadelphia Section was held with an ophthalmological society of Philadelphia.

The following is the program for future meetings:

MONDAY, DECEMBER 8.

Joint Meeting with Philadelphia Section A. I. E. E.

"Brightness Measurements versus Illumination Measurements."

By Dr. Herbert E. Ives.

"Railway Car Lighting."

By Mr. Geo. H. Hulse.

"The Mercury Quartz Tube Lamp."

By Mr. Buckman.

FRIDAY, JANUARY 6.

"Deficiencies of the Method of Flicker for the Photometry of Lights of Different Colors."

By Prof. C. E. Ferree.

SATURDAY, FEBRUARY 7.

Meeting under the Auspices of Drexel Institute.

"Light and How to Use It."

By Mr. C. O. Bond, President of I. E. S.

WEDNESDAY, FEBRUARY 18.

Joint Meeting with Franklin Institute.

"Artificial Daylight."

By Dr. Herbert E. Ives.

FRIDAY, MARCH 20.

"Lighting and Signalling Systems of Subways."

By Mr. F. D. Bartlett.

"The Sun—The Master Lamp."

By Prof. James Barnes.

THURSDAY, APRIL 9.

Joint Meeting with Franklin Institute.

"Recent Developments in the Art of Illumination."

By Mr. Preston S. Millar.

FRIDAY, APRIL 17.

"The Structure of the Normal Eye and its Ability to Protect Itself Against Ordinary Light."

By Dr. Wendell Reber.

"Glassware for Illumination and Other Purposes."

By Mr. James Gillinder.

FRIDAY, MAY 15.

Mass Meeting of all the Engineering Societies of Philadelphia and Vicinity.

Special Program to be arranged and to include an address on

"The Relation of Engineers to the Progress of Civilization."

By Dr. Chas. Proteus Steinmetz.

PITTSBURGH SECTION

A meeting of the Pittsburgh Section was held October 17 in the Auditorium of the Engineering Society of Western Pennsylvania. Sixteen members and guests were present. Mr. L. L. Hopkins reviewed the proceedings of the Pittsburgh Convention and Dr. H. H. Turner gave a paper entitled "The Essential Elements of Vision." Dr. Turner's paper was supplemented with a series of slides and models.

The following program of meetings has been announced tentatively:

November—"Technical Discussion of the Elements of Lighting" by Prof. Hower and others.

December—A joint meeting with the Pittsburgh Section of the American Institute of Electrical Engineers. A Central Station paper will be presented by H. N. Muller of the Duquesne Light Company.

January—A paper to be selected by the members from Cleveland. The subject will be announced later.

February—"Railroad Yard Lighting" by A. C. Cotton and A. Kirschberg of the Pennsylvania Railroad Company.

March—A gas lighting subject; the speaker to be announced later.

April—"Developments of Flame Carbon Arc Lamps" by C. E. Stephens.

May—"Store Lighting"; speaker to be announced later.

June—Open.

New Members.

The following twelve applicants were elected members of the society at a meeting of the Council, November 14, 1913.

De Vine, H. C.
Manager, Pittsburgh Lamp, Brass & Glass Company, 731 Arch Street, Philadelphia, Pa.

Fitch, W. S.
Construction Engineer, Dennison Mfg. Company, Framingham, Mass.

Hageman, Jacques R. G.
Engineering Department, Bell Telephone Company, 2129 Ritner Street, Philadelphia, Pa.

Hass, Henry P.
Chief Inspector, Department of Tests, N. Y. N. H. & H. R. R. Company, New Haven, Conn.

Hicks, Leslie R.
Superintendent, Fall River Electric Light Company, 14 Bedford Street, Fall River, Mass.

Hostetter, John S.
Manager Fixture Department, Barden Electric & Machinery Company, 111 Main Street, Houston, Tex.

Johnston, R. J.
Testing Department, General Electric Company, Schenectady, N. Y.

Jordan, Horace W.
Illuminating Engineer, Edison Electric Illuminating Company of Boston, 39 Boylston Street, Boston, Mass.

Mercer, J. M.
Car Lighting Engineer, The Adams & Westlake Company, 319 West Ontario Street, Chicago, Ill.

Osborn, Frederick A.
Professor of Physics, University of Washington, Seattle, Wash.

Staley, V. L.
General Electric Company, Harrison, N. J.

Taylor, Frank C.
Assistant in Electrical Engineering Department, Rochester Railway & Light Company, Rochester, N. Y.

Additional Sustaining Members.

The following organizations were recently elected sustaining members:

Gill Brothers Company.
101 Park Avenue, New York, N. Y.
Official Representative: John Beiswanger.

Jefferson Glass Compa y.
Follansbee, W. Va.

Koerting & Matheisen.
22 East 21st Street, New York, N. Y.
Official Representative: Charles Arnold Chapin.

The Electric Power Company, Ltd.
506 Confederation Life Building, Toronto, Can.
Official Representative: Wills Machbachlan.

Personal.

Mr. C. O. Bond, president of the Illuminating Engineering Society, was recently awarded the Beal medal of the American Gas Institute for the best paper read at the 1912 Convention of that organization. Mr. Bond's paper, entitled "Photometry of Incandescent Gas Lamps," appears in the 1913 *Proceedings* of the Institute.

Mr. W. H. Gartley, a past president of the Illuminating Engineering Society, was recently elected President of the American Gas Institute.

Hollis Godfrey, Ph. B., Sc. D., F. R. G. S., was recently elected president of the Drexel Institute of Art, Science and Industry, Philadelphia, by the trustees of that institution. He will assume the presidency December 1, 1913. Dr. Godfrey is well known as an educator, a business man and engineer. He organized the department of science in the High School of Practical Arts in Boston, and for four years served as its head. He also spent six years in night school work in Boston along the same lines which the Drexel Institute is being conducted. With two other leaders in education he organized the Garfield school, and for two years directed its policy in the teaching of science, and in extension work. For three years he served as a member of the Board of Visitors of Tufts College, and was a member of the alumni council of the Massachusetts Institute of Technology for two years. He has outlined a course in industrial engineering for the Society of Promotion of Engineering Education, and has been a lecturer and consultant in a number of educational institutions, among which are Dartmouth College, Simmons College and the University of Wisconsin. For several years past he has been chief of the Bureau of Gas of Philadelphia, and recently devoted an exhaustive study to the organization and operation of the water bureau of the latter city. In addition to outlining a new lighting plan for Atlantic City, he has also been a consultant in the restoration of the lighting of Independence Square, Philadelphia. He is the author of a book on sanitary engineering entitled "The Health of the City," two books on "Chemistry," and a number of monographs on scientific subjects. Besides having membership in a number of clubs Dr. Godfrey is a member of the Phi Beta Kappa and the Theta Delta Chi fraternities, the American Society of Mechanical Engineers, the American Public Health Society and the Illuminating Engineering Society.

Obituary.

George H. Hoffman, a district manager of the Philadelphia Electric Company, died in Philadelphia, November 3, after a brief illness. He was born in New York City, December 22, 1848, and received a public school education. From 1873 to 1877 Mr. Hoffman was a member of the New York School Board, and from 1882 to 1889 was a member of the City Council. He was appointed by President Cleveland Assistant United States Appraiser in 1885, and served in this position until 1889. Later he engaged in the wool business and was also connected with the *Nord-Amerika,* a German newspaper. In June, 1895, he identified himself with the electric lighting industry as manager of the West End Electric Light Company of Philadelphia. In 1901, when the West End, Columbia, Diamond and Wissahickon companies were consolidated into the Philadelphia Electric Company, he was made manager of the northwestern district of the company. He was a charter member of the Pen and Pencil Club of Philadelphia, and had served as vice-president of the International League of Press Clubs. He took an active interest in the affairs of the Philadelphia Section of the Illuminating Engineering Society besides being a member of several other societies.

TRANSACTIONS

OF THE

Illuminating Engineering Society

NOVEMBER, 1913

PART II

Papers, Discussions and Reports

[NOVEMBER, 1913]

CONTENTS -- PART II

THE COOLING EFFECT OF LEADING-IN WIRES UPON THE FILAMENTS OF TUNGSTEN INCANDESCENT LAMPS OF THE STREET SERIES TYPE.*

BY T. H. AMRINE.

Synopsis: This study of the cooling effect of the leads upon the filaments of street series lamps was undertaken as a part of a general investigation into the effect that dimensions and material of lead wires and supports have upon incandescent lamp design. The method used was to calculate the average per cent. of normal candle-power and average per cent. of normal wattage over the cooled portion of the filament by means of measurements made upon two sets of lamps of exactly the same construction except having different filament lengths. The variation of the cooling effect with lead material, lead diameter, lead length, filament diameter and filament material was determined. The cooling effect of any lead upon any filament was shown to be dependent mainly upon (1) the resistance to heat flow presented by the leads and the cooled portion of the filament, (2) the diameter of the filament and (3) the maximum temperature of the filament, *i. e.*, the temperature of the uncooled portion. For lamps having lead and filament dimensions encountered in street series lamps the cooling effect decreases with increase of lead length, with decrease in lead diameter and with increase in thermal resistance of the material of the lead. With lamps having the same lead construction but with filaments of different diameters the cooling effect shows a maximum at a value of filament diameter which is dependent upon the lead construction used.

The accuracy with which it is possible to predetermine the dimensions of the filament of a lamp having the desired candle-power, wattage and construction is at present very largely limited by the lack of knowledge of the amount of cooling effect of lead wires and supporting anchors. A length of drawn tungsten wire of a certain diameter and carrying a certain current will, when subject to no cooling effect, consume a definite number of watts per centimeter length and will produce an equally exact, if not so readily determined, candle-power per unit length. The determination of the total wattage and total flux

* A paper read at the seventh annual convention of the Illuminating Engineering Society, Pittsburgh, Pa., September 22-26, 1913.

of light from such a filament of any length would, therefore, involve only multiplication and a correction for the light absorbed by the bulb. The presence of leading-in wires and anchors subjects the filament to a cooling effect which is dependent upon their material and dimensions and upon the number of anchors. This cooling effect makes the average watts per centimeter and candle-power per centimeter of a given filament dependent not solely upon the dimensions of the filament and the current flowing through it, but also upon the construction of the lamp as regards leads and anchors.

The work reported in this paper was undertaken as a part of a general investigation into the effect that dimensions and material of lead wires and supports have upon incandescent lamp design. The study of the cooling effect of the leads in high current, low-voltage lamps, such as street series lamps was taken up first on account of the fact that the leads of these lamps cause heat conduction losses that are large and relatively easily measured. An investigation into the effect which changes in such variables as lead diameter, lead length, material of lead, filament diameter, filament length and filament temperature, can, therefore, be carried on with such lamps and data obtained which is of value not only in connection with the design of lamps of this type, but also in that it will furnish some information as to the general laws governing the relation between cooling effect and the variables mentioned. This information as to the approximate nature of these laws will serve as a guide in the investigations upon the ordinary multiple lamp where the cooling effect is less marked and less easily measured.

Hyde, Cady and Worthing have published* the results of an investigation into the energy losses in lamps of the multiple type and have shown the variation in the conduction losses due to change in filament material and filament temperature. The variations due to lead dimensions and material and filament diameters were not determined in this investigation, and no data seems to have been published on this phase of the subject.

* A Study of The Energy Losses in Electric Incandescent Lamps. E. P. Hyde, F. E. Cady, A. G. Worthing. Trans. I. E. S., Vol. VI., No. 4, page 238.

METHODS OF INVESTIGATION.

A number of methods of carrying out this investigation are possible and were considered before the work was taken up. A strictly mathematical method can, of course, be employed, the temperature of the filament at different distances from the leads being calculated and the total changes in candle-power and wattage due to the cooling effect determined therefrom. On account of the number of variables and complexity of the problem, the mathematical method yields a rather unwieldy equation. Its accuracy is dependent upon the thermal constants of tungsten at high temperatures and upon the law of their change with the temperature and upon the thermal resistance of the welded joints between the lead wire and filament and other factors upon which there is no good data. A much preferable method is to measure directly the temperature of the filament at points at different distances from the leads by some means such as a thermocouple made of very fine wires or by an optical pyrometer such as was used by Hyde, Cady and Worthing. These temperature measurements are laborious to make by either method and the time required to cover the ground which was desired to cover in this investigation would be very great. By the optical pyrometer method measurements of temperature over the first two or three millimeters of the filament adjacent to the lead of a lamp of the series type are very unsatisfactory on account of the very low luminosity of the filament at these points. For these reasons the methods involving temperature measurements were not adopted, though for the purposes of studying the temperature conditions adjacent to the leads a considerable number of tests were made by a method only slightly modified from that used by Hyde, Cady and Worthing. The modification was simply the interchanging the positions of the lamp under test and the comparison lamp so as to permit of the latter burning at a lower temperature.

The method adopted was to arrive at the figure for the average per cent. of normal wattage and average per cent. of normal candle-power over the cooled portion of the filament by means of measurements made upon two sets of lamps having different lengths of filaments. This method was made possible

by the fact that modern tungsten wire drawing methods permit of the manufacture of wire of almost exactly uniform diameter and composition throughout its length. The average candle-power and wattage of two sets of lamps of exactly the same construction can, therefore, be depended upon to be very nearly the same. Also the difference between the average candle-power, for instance, of a set of lamps of a certain construction and that of another set of exactly the same construction, except for filament length, will be the candle-power of an uncooled portion of the filament equal in length to the difference between the average filament lengths of the two lots of lamps.

Assume that it is desired to determine the cooling effect upon a filament of a given diameter of a lead of given dimensions and material. Two lamps are made from wire of the correct diameter taken from the same spool and having the desired dimensions and material of leads and of exactly the same construction throughout, except that one has a filament of length l and the other a filament of length l'. Let c and w represent the candle-power per centimeter length and the watts per centimeter length respectively of the uncooled portion of the filament with a current passing through the lamp which will bring this uncooled portion of the filament to the desired temperature—say that corresponding to normal operation. Let a equal the total length of the cooled portion of the filament in each case. This will be the same for two lamps of similar construction except for filament length, if the filament is longer than a certain minimum length. The expressions for the total candle-power and total watts of the two lamps will be

$C = aK + (l - a)c$, for lamp of filament length l

$W = aP + (l - a)w$, for lamp of filament length l

Similarly,

$C' = aK + (l' - a)c$, for lamp of filament length l'

$W' = aP + (l' - a)w$, for lamp of filament length l'

where K is the average per cent. candle-power and P the average per cent. wattage over a cooled portion of the filament a centimeters long. These figures for average per cent. are based upon the candle-power and wattage of a centimeters of the uncooled portion of the filament.

C and C′ can be determined by careful photometer measurements and W and W′ by means of a potentiometer. An investigation with an optical pyrometer showed that in none of the lamp constructions which it was planned to investigate was there any cooling effect at a distance greater than two centimeters. For the sake of uniformity this distance of 2 centimeters was adopted arbitrarily as the length of the cooled portion adjacent to one lead. Hence a is equal to 4 centimeters. Between the above equations, K and P and the values of c and w can be determined, since l, l′, C, C′, W, W′ and a are known. The values of K and P based on the standard distances of 2 centimeters from each lead, are measures of the cooling effect. By using these values and the values of c and w, as determined above, one can calculate the candle-power and watts of an ideal filament (*i.e.*, one which is not subject to a cooling effect) of length l or l′ and compare the values obtained with C, C′, and W and W′.

A quantity M was also calculated for each case studied. This quantity is the per cent. difference between the wattage of an ideal lamp with an uncooled filament of 10 centimeters length and that of a lamp of any given lead construction of the same candle-power and having a filament of the same diameter and operating at the same current. M expresses by one quantity the result of cooling effect on both the candle-power and watts of a filament.

This method has the advantage that the work required for one determination can be carried out in a reasonable length of time so that the various experiments can be made upon a sufficient number of lamps so that a good average result can be obtained. In this work on an average of four lamps of each construction were investigated so that it is felt that fairly good average values were obtained.

EXPERIMENTAL RESULTS.

The lamps used in the experiments were similar in construction to the regular street series tungsten lamps except that there were no anchors or supports used. All lamps had drawn wire tungsten filaments and were made in straight sided bulbs of 4⅜ inches (11.11 centimeters) maximum diameter (commercially known

as S-35 bulb) and with a skirted screw base (commercially known as No. 108 base) and with the same size of glass stems. The dimensions of the lead wires, of course, were different in the different experiments. Fig. 1 shows the type of lamps experimented upon.

The routine followed in carrying out these experiments was as follows: Assuming, for example, it was desired to compare the cooling effect on a filament of a given diameter and temperature, of leads of two different diameters. Ten lamps were made up with filaments taken from the same sample of wire with each of the desired lead constructions, all lamps of each lot of ten being exactly alike except that five had filaments of about 6 centimeters length and five had filaments of about 15.5 centimeters length. After the filaments were mounted they were each carefullly measured before sealing-in for filament length between leads. The lamps were exhausted in the regular manner, based and then all carefully measured, at the amperes to give the desired temperature, for candle-power upon a precision photometer and for wattage by means of a potentiometer. The values for K, the average per cent. of normal candle-power, and P, the average per cent. of normal wattage each over a portion of filament to a distance of 2 centimeters from each lead, were then calculated as shown above. From these values the value of M, the per cent. wattage change due to cooling, were calculated. The average figures obtained with each lot of lamps were used as the correct values of K, P and M.

On account of the fact that the accuracy of the wattage measurements is considerably better than that of the candle-power measurements, the curves shown were based upon the wattage measurements. From the relation between K and P determined from all the experimental data, the points on the curves for K as plotted were calculated from the values of P. In this way the K curves were "smoothed out" and made to conform with the P curves. By this plan it was thought that the relation between K and different variables as lead length, lead diameter, etc., are more accurately shown and that the absolute values of K, as plotted, are probably as accurate as the individual experimental values obtained.

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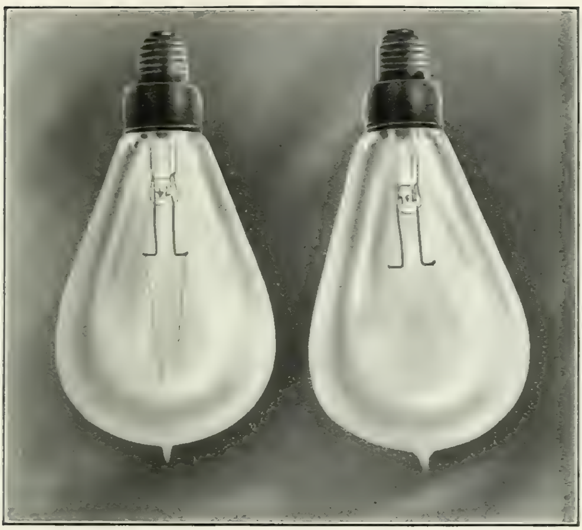


Fig. 1.

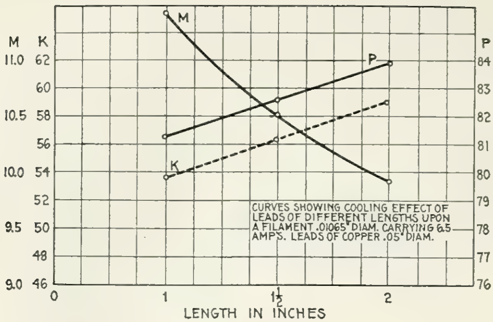


Fig. 2.

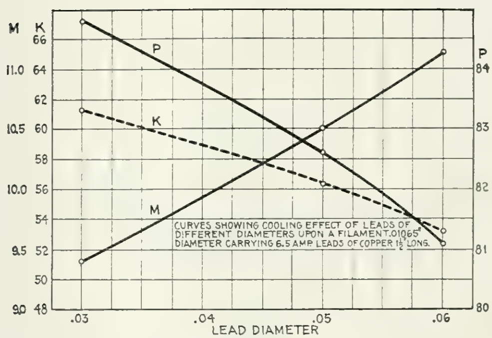


Fig. 3.

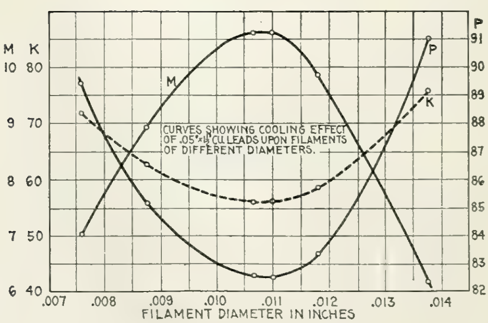


Fig. 4.

Fig. 2 shows the values obtained at operating efficiency for K, P and M for lamps having different lengths of leads. In these and in the following curves K is the average per cent. candle-power and P the average per cent. wattage over the two centimeters of the filament adjacent to each lead; that is, the section of the filament which embraces the cooled portion. These values are based upon the candle-power and wattage of two centimeters of a similar but uncooled filament carrying the same current. M is the per cent. difference in wattage between an ideal filament and a cooled filament as defined under the heading of Method of Investigation. These curves indicate that for the lead construction used the longer the lead, the less the cooling effect as is shown by the higher values of K and P and the lower values of M. The lead length as used in this connection is taken as the length of lead from filament to the glass stem.

Fig. 3 shows the greater cooling effect of large diameter leads as compared with small diameter leads of the same material.

In order to compare the relative cooling effects of copper and nickel leads of the same dimensions, K, P and M were determined for a 6.5 ampere filament using leads 0.050 in. in diameter and 1½ in. (3.81 cm.) long in each case. The values obtained were as follows:

	P	K	M
Copper...........................	82.6	56.3	10.52
Nickle...........................	90.6	67.5	9.24

The influence of filament diameter upon cooling effect is shown by the curves of Fig. 4. The rather unexpected shape which these curves take is no doubt accounted for by the fact that the total resistance to heat flow from the filament is made up of three parts, that due to the leads, that due to the welded joints and that due to the cooled portion of the filament. With the same size leads and the same sort of a welded joint this total resistance might be expected to show a minimum at some value of filament diameter. In a lamp of the construction studied this minimum occurs at about 0.0108 in. diameter.

Fig. 5 is a set of curves which shows the variation in cooling effect with the filament temperature. These curves are plotted between "per cent. of normal $\frac{I}{d^{3/2}}$" and "per cent. of normal P,"

"per cent. of normal K and "per cent. of normal M." The quantity $\frac{I}{d^{3/2}}$ is a measure of filament temperature, I representing the current through the filament and *d* the diameter of the filament. A value of $\frac{I}{d^{3/2}}$ equal to 0.0059 was taken as normal. This corresponds to approximately 1 watt per projected candle-

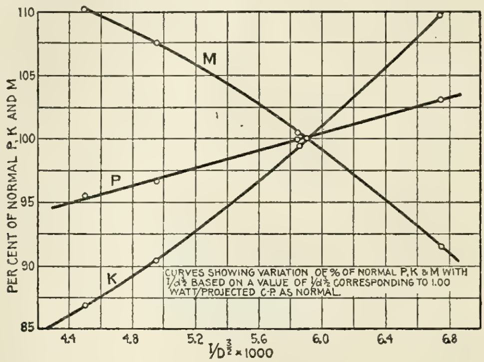


Fig. 5.

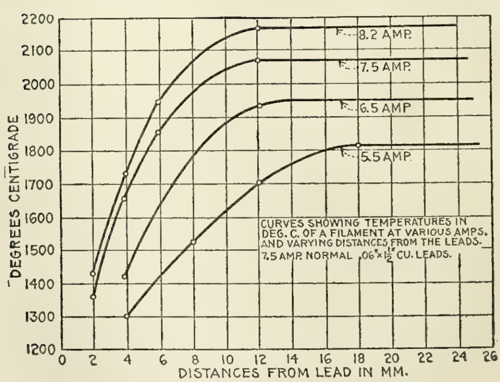


Fig. 6.

power. It also corresponds approximately to the filament temperatures used in the measurements made upon the relative cooling effects of leads of different diameters, lengths and material. These curves indicate that with higher filament temperatures, *i. e.*, lower watts per candle-power, the cooling effect is less

marked. This can be readily noticed in a lamp if the cooled portion of a filament is observed first with a large current flowing and then with a smaller one. In the latter case the filament is cooled out to a considerably greater distance from the lead. The curves of Fig. 6, the data of which was obtained by the optical pyrometer method, show the decrease in temperature near the leads and the greater cooling effect at higher temperatures.

A study of the foregoing data shows that the cooling effect of any lead upon any filament is dependent mainly upon three things: (1) the resistance to heat flow presented by the leads and the cooled portion of the filament, (2) the diameter of the filament and (3) the maximum temperature of the filament, *i. e.*, the

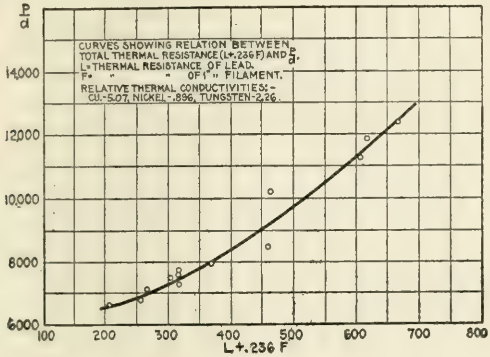


Fig. 7.

temperature of the uncooled portion. With a given maximum filament temperature and a given thermal resistance due to the leads and the cooled portion of the filament the same number of watts will be lost by conduction (neglecting differences due to the amount of heat radiated by the lead and cooled portion of the filament). With a given number of watts escaping by conduction there will, of course, be a greater per cent. reduction in wattage with a filament of small diameter than one with a filament of a larger diameter. By plotting the data obtained with "total thermal resistance," that is, the resistance of the lead plus that due to the cooled portion of the filament, as abscissae and $\frac{P}{d}$ as ordinates, where d is filament diameter, an approximately

smooth curve is obtained. In this curve, Fig. 7, the "total thermal resistance" is taken to include 0.236 in. of the filament and is calculated using lengths in inches, diameters in inches and the relative thermal conductivity of the materials as follows:

Copper	5.07
Tungsten	2.26
Nickel	0.876

The curve includes the data taken upon leads of different diameters, lengths and materials and different filament diameters and should show, over the range covered by the experiments, approximately the cooling effect of any lead upon a filament of any diameter. It does not, however, take into consideration the influence of change in thermal conductivity with temperature,

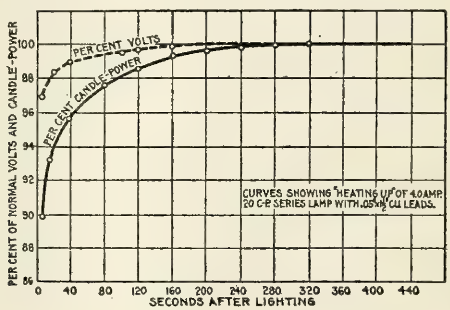


Fig. 8.

effect of radiation from the leads, etc. The filament temperatures correspond to $\frac{I}{d^{3/2}}$ equal to 0.0059, that is, approximately one watt per projected candle-power. By the use of this curve and the P curve of Fig. 5, one can determine approximately the values of P for filaments at other temperatures. Knowing that K varies about as the cube of P the value of the average per cent. candle-power over the cooled portion of a filament with any lead construction can be determined.

The data obtained in the experiments described show that there is a marked cooling effect in lamps of the construction used. That this cooling effect is of vastly more than mere scientific interest in the case of these lamps is, perhaps, not generally recognized

except by lamp specialists. However, in the design and rating of and measurements upon these lamps this cooling effect must be taken into practical consideration.

In Fig. 8 are shown curves which demonstrate that the cooling effect of leads must be taken into consideration in all careful measurements of series lamps. These curves were obtained by holding the normal current through the lamp while the voltage and candle-power were measured at short intervals of time. Due to the cooling effect of the leads, the lamp does not come up to full normal candle-power until several minutes after the current is turned on. Errors that would be quite serious in careful work are caused if series lamps are photometered or measured for volts at amperes without taking the precaution first to allow the

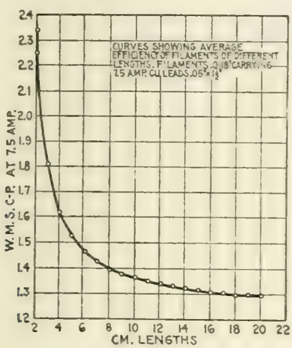


Fig. 9.

lamp to heat up thoroughly. For instance, an error of about 1.3 candle-power or 6.5 per cent. would be caused in photometering a 20 candle-power, 4.0 ampere series lamp 20 seconds after lighting up instead of allowing it to heat up thoroughly.

Due mainly to this influence of the cooling effect of leads, it is impracticable to make, for instance, 7.5 street series lamps of the various candle-power sizes at the same efficiency rating. Lamps of the same current rating have, of course, a candle-power almost proportional to the filament length. The loss in candle-power and the decrease in wattage for a low candle-power lamp of a given diameter of filament and a given current flowing is a much larger per cent. of the total for a short filament or low candle-power lamp than with a long filament or high candle-

power lamp. Hence, if the current in the short filament lamp is increased until the filament is operating at the same watts per mean spherical candle-power then its temperature out on the uncooled portion of the filament is much greater than the maximum temperature of the long filament lamp and will, therefore, give a much shorter life. In Fig. 9 is a curve which shows the watts per mean spherical candle-power of lamps made with filaments of the same diameter and with the same current passing through them, but of different filament lengths. It shows that at the same amperes a short filament is operating at a very much poorer efficiency than a long filament and if operated at the same efficiency would give a very poor life.

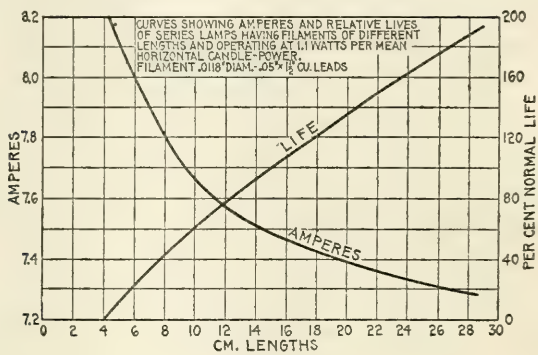


Fig. 10.

In Fig. 10 is shown what would be the effect if street series lamps of a given wire size and current with their great cooling effects were rated at the same watts per mean horizontal candle-power regardless of their filament lengths. These curves assume 7.5 ampere lamps of different candle-powers, that is, different filament lengths. They are assumed all to be rated at 1.1 watts per mean horizontal candle-power. The curve marked "amperes" shows the amperes that it would be necessary to pass through the filaments of the various lengths in order to bring them to the same mean horizontal efficiency. The great increase in amperes necessary to bring the short filaments up to efficiency, of course, very seriously cuts down their lives, since a lamp's life is determined by the temperature of the hottest part of the filament. This decrease in life is shown by the curve marked "life." The

character of these curves is almost wholly brought about by the cooling effect of the leads, though the change in spherical reduction factor with the filament length enters to a minor extent.

By going to the extremes in cooling effect by using filaments so short that they are cooled over practically their entire length, one can arrive at the unusual condition of having two lamps with filaments of the same diameter and differing in length by 30 per cent. or more but with the same voltage and candle-power. This is brought about by the difference in the volt candle-power characteristic caused by the difference in the cooling effect of the leads on the two filaments. Fig. 11 shows the volt candle-power

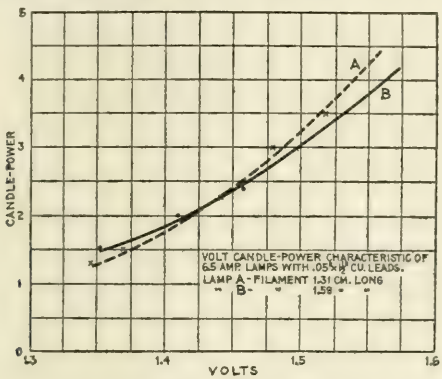


Fig. 11.

characteristics of two lamps made exactly alike except for filament length. Lamp A had a filament 1.31 cm. long, lamp B, 1.59 cm. long. Both filaments were made of wire 0.0118 in. diameter taken from the same spool. The characteristics of the two lamps intersect and show that both lamps give 2.27 candle-power at 1.44 volts. In other words, if one had a lamp of the construction of lamp B, he could remove 17.5 per cent. of the filament and still have a lamp of the same candle-power and voltage.

Notwithstanding the magnitude of the cooling effect on lamps of the street series type it is for the most part impracticable to let this factor determine the lead construction of these lamps. That is, it is usually not feasible in practice to so construct a lamp that the losses due to cooling effect approach a minimum. Other conditions will usually limit the designer's choice of lead

dimensions and materials. The appearance of the lamp, bulb dimensions and added energy losses due to electrical resistance will usually limit the length of leads. The vapor pressure, and electrical resistance of the material of the lead will usually determine its diameter and these factors as well as the ease with which the metal may be subjected to the various manufacturing processes will determine the material of the lead. A knowledge of the manner in which the cooling effect varies with lead material and dimensions is therefore chiefly of importance in that it enables one to make the proper allowances in candle-power, watts and volts in designing a lamp to a given specification.

The author wishes to acknowledge his indebtedness to Mr. L. M. Moss, who assisted in all the experimental work and in the preparation of the data for this paper.

DISCUSSION.

Mr. Evan J. Edwards: I have consulted Mr. Amrine regarding a demonstration which was used in the presentation of the paper "Recent Improvement in Incandescent Lamp Manufacture," and I believe it worth while to repeat it, for it shows in a very striking manner the cooling of the filament adjacent to supports and leading-in wires.*

There is one interesting point concerning the cause of the cooling which Mr. Amrine has not emphasized, and that is the changed rate at which electrical energy appears as heat in the cooled portions. The fundamental cause of the reduced temperature is, of course, the conduction of heat to the supports or leading-in wires. But the reduced temperature condition, in the case of metal filaments, brings about a lowering of the resistance which also contributed to lowering of the temperature. The current in all portions of the filament is the same, and therefore, the rate at which heat is received by any portion of the filament is proportional to the resistance of that portion.

Changed resistance therefore has the effect of helping to lower the temperature of the cooled portion of metal filaments because

* A stereopticon was used to project the direct image of the lighted filament of a large special lamp on a background lighted by the regular light source of the lantern. After adjustments of current in the special lamp were made, the hottest parts of the filament appeared as bright lines and the cooled portions as dark lines.

of their positive resistance-temperature coefficient. The opposite is true for the negative coefficient carbon filaments.

MR. M. LUCKIESH: At the bottom of the tenth page Mr. Amrine states "These curves indicate that with higher filament temperatures, *i. e.*, lower watts per candle-power, the cooling effect is less marked." This is at once evident from the fundamental laws of radiation. As the temperature of the filament increases, the conduction loss becomes proportionately less because it increases approximately directly with the temperature while the candle-power is a function of a higher power of the temperature. Therefore as the temperature of the filament is increased the candle-power will increase much more rapidly than the conduction losses in the leading-in wires.

MR. T. H. AMRINE: I wish to add that the lamp with the shorter filament, lamp A, has a wattage of 11.07 and lamp B has a wattage of 12.25 at the voltage which makes the candle-powers of the two lamps equal, that is, at 1.44 volts.

SOME THEORETICAL CONSIDERATIONS OF LIGHT PRODUCTION.*

BY W. A. DARRAH.

Synopsis: This paper sets forth some of the inherent limitations of the various electric illuminants now in use, and discusses briefly the effect of these limitations upon the progress of the art of illumination. The basic theory of light production by the acceleration of electric charges is analysed with a view to indicating the relative possibilities of the various types of illuminants particularly the arc and the incandescent lamp. The structure of the atom is considered in the light of modern theories, and some general deductions made regarding the properties which a substance is likely to exhibit if well adapted for use as a radiating body. A tentative explanation of the action of selective radiation is given, and of the part which this phenomenon plays in present illuminants. It is demonstrated that to secure high luminous efficiencies selective radiation must be relied upon, and therefore unless new materials are discovered which exhibit selective radiation, while in the solid state, the efficiency of the electric arc will remain materially higher than the efficiency of the so-called incandescent lamp, where electrical energy is transformed into heat and then into light by means of the resistance of a conductor.

It is proposed in this paper to discuss some theoretical phases of light production with a view of indicating how these considerations have influenced the progress of the art of illumination and their probable effect upon future developments in the direction of higher efficiencies.

No claim is made here for original theories, as modern conceptions and methods of mathematical analysis have been used freely; but an effort has been made to apply these theories in a way to indicate the trend of engineering progress.

The generally accepted, and most satisfactory conception of light, is, that of a transverse electromagnetic vibration, of the ether, which travels in straight lines at a speed of approximately 180,000 miles per second. Having identified light as an electromagnetic vibration it is necessary to differentiate it from other

* A paper read at the seventh annual convention of the Illuminating Engineering Society, Pittsburgh, Pa., September 22-26, 1913.

electromagnetic vibrations, as the radiation utilized in wireless telegraphy, the so-called "radiant heat," and the large class of radiations possessing varying properties, and known as x-rays. In present theories the frequency of the vibration (or what is practically its reciprocal, the wave-length) is considered sufficient to supply the identification, although it seems probable to the writer that under some conditions, the wave form of the vibration may be as important as the frequency. Omitting this point, the zone covered by visible electromagnetic radiations is comparatively narrow, comprising not more than one octave out of 45 of the entire section between the longest electric wave, and the shortest, ultra-violet wave. In other words, only those vibrations which fall between 400×10^{12} and 800×10^{12} cycles per second are visible, assuming the waves to be simple harmonics.

Whenever an electric charge has its rate of motion changed the ether is disturbed, a certain amount of energy being transferred or radiated from the body. In the case in which the charged particle is accelerated for a time dt with an acceleration of "a" the energy radiated is $E = \frac{2}{3} \frac{e^2a^2}{V} dt$, where e represents the charge, and V the velocity of light.* Therefore, dividing by the time during which the change takes place, the rate at which energy is emitted is $\frac{2e^2a^2}{3V}$.

Light production is always associated with matter and usually matter heated to a high temperature. It is evident from the equation of the rate of energy emission that since all values must be divided by V, the velocity of light 2.7×10^{10} cm. per second either enormously large charges or very high accelerations must be employed to produce any appreciable amount of radiation. Practically, for mechanical reasons, it is impossible to accelerate charged bodies of a size which can be handled, with sufficient rapidity to produce any useful radiation. Therefore, one must discover, if possible, some smaller units which have a higher ratio of charge to mass, than do "material" objects.

If the case of bodies moving in simple harmonic motion,

* J. J. Thompson, *Electricity and Magnetism.*

rotation, for instance, be considered, it will be found that the acceleration varies as the square of the velocity of rotation, and consequently the equation of energy radiation becomes $E = \frac{2e^2w^4}{3V}$ K per cycle where w = the speed of rotation, and K is constant. Also since the acceleration passes through zero twice each revolution, it follows that the frequency of the emitted radiation is w.

It is known that for visible radiation w must lie between 400×10^{12} and 800×10^{12}, the color of the radiated light depending upon the frequency.

It also follows that as $E = \frac{2e^2w^4}{3V} K$ = the energy radiated per cycle, $E_t = \int \frac{2e^2w^4 K dt}{3V}$ = total energy radiated, and that if there are n charges being accelerated the total energy from all charges will be $E_t = 2\int \frac{e^2w^4 K n dt}{3V}$ or making the constants equal to C, $E_t = C\int e^2w^4 n dt$.

It is of interest to note in passing, the consistency of this formula with that which covers the radiation of energy from a heated body (Stefan's Law, which is based on experiment) viz., $E = C\,T^4$ where T = the absolute temperature, in that the frequency of rotation which varies directly as the temperature occurs as the fourth power.

The modern conception of matter assumes that the atom consists of a central positive charge (which may or may not be centered upon a material point) and a number of negative charges (or electrons) which are in rapid motion around the central charge. The charges are all units and equal, the different properties of matter being derived by the grouping and numbers of the charges, and by the groupings of the atoms and molecules.

Since then in all matter there is an unlimited number of these groups of electrical charges moving about the central charge of opposite sign, the outer charges being in rapid motion,

one should expect, due to the motion of the charges, a continuous radiation of electromagnetic waves from matter under normal conditions. This is found in all bodies and takes place as the so-called "heat radiation" in accordance with Wein's law, but as all surrounding bodies are also radiating and conducting heat to all other bodies, the internal energy of the system is not depleted.

If, however, the temperature of a body be increased the acceleration of the electrons will be increased; and thus also the energy radiated and the frequency of the radiation will be increased, until at length those frequencies which lie in the visible spectrum are reached and light produced. The wavelengths of the radiations so produced will cover the entire range of electromagnetic waves since the apparent temperature is an average of the velocities of each atom, and the average or apparent color will, of course, depend on the average temperature.

If the temperature is raised until the substance is vaporized, in other words, until comparatively unrestrained motion can take place among the electrons, a condition resembling resonance is reached in which the greater part of the radiation of a portion of the atoms is confined to a definite group of lines. This is the characteristic of the spectrum observed when sodium, potassium, calcium, salts, etc., are heated in a Bunsen burner. The effect of this apparent selective action is to absorb energy of all wave-lengths and to transform a considerable portion of this absorbed energy into vibrations of a definite wave-length. This is what is known as selective radiation.

Returning to considerations of the structure of the atom, it has been demonstrated* mathematically that assuming a given number of electrons in each atom moving under definite conditions they must take definite configurations. Since varying the temperatures varies the speed with which the electrons move, and therefore causes different configurations which are due to different rates of rotation, one should expect the radiant spectrum to vary with the frequency of resonance for the charged particles.

An interesting converse effect of this is the phenomenon of markedly increasing the motion of the electrons of an atom by

* N.-Bore and Albert Crebore, *Philosophical Magazine*, July, 1913.

the action of light of a definite wave-length. This is applied practically in photography where chemical reactions are caused by the acceleration produced by light on the electrons of the silver atom. The photo-electric effect where electrons are actually torn from the mass of a conductor in a vacuum by the influence of light of a frequency in resonance with the motion of the electrons is another example of the action of light upon the electrons within the atom. The effect of temperature to raise the rate of rotation of the electron sufficiently to produce resonance with the exciting wave is illustrated in those photo-electric cells which are insensitive to light at ordinary temperatures, but which become exceedingly sensitive at an elevated temperature.

The theoretically ideal illuminant is one which approximates daylight, and which produces a spectrum of the frequencies and quantities necessary to approximate daylight. It is obvious therefore, that if it is desired to confine the radiation to a limited range, selective radiation must be relied upon. Since in non-selective or temperature radiation, due to the constrained conditions surrounding the motion of the radiators as a result of their numbers and proximity, the vibrations cover all frequencies and therefore the quantity of energy radiated in this way at any one frequency will depend upon the number of particles moving at the necessary frequency. Since there will be relatively few atoms at the extreme temperatures, there will be relatively little radiation at the extreme wave lengths. The greater part of the radiation takes place at the average frequencies, and a curve plotted between wave length and energy emitted will resemble the probability curve.

In choosing a measure of the efficiency with which the energy supplied to a body is converted into useful visible radiation, the assumption is made that all energy supplied is radiated in some form. The efficiency, therefore, becomes the ratio of the total energy radiation to the energy radiated within the range of visibility, and is used here in that sense.

A consideration of the limited efficiencies theoretically possible from incandescence or black body radiation alone will serve to emphasize the advantages of selective radiation. Thus assum-

ing a frequency of 500×10^{12} as an average for normal visibility and taking Wein's Law as a basis, the energy at frequency w, $= E_w = \frac{Cw^5}{V^5} (e)^{\frac{5E}{V}}$, where the letters have the same significance as previously except that C is a constant equal to about 14,395 and $e =$ the base of the natural logarithm system.

This gives approximately 6,000° absolute as the necessary temperature for maximum efficiency of radiation from an incandescent body. The efficiency at this temperature while theoretically about 10 per cent. cannot be approached in actual practice since the highest known temperature (the vaporization point of carbon) is about 3,800°. At this temperature the efficiency of radiation of light by incandescence is about 5 per cent. while at the melting point of tungsten the efficiency is about 3 per cent.

It is evident, therefore, that unless a conducting material is discovered having higher melting point than carbon, luminous efficiencies from incandescent bodies must remain limited. At the present time it is, of course, the vaporization of the filament of an incandescent lamp which limits the safe temperature, but even when this difficulty has been removed as seems commercially possible in some cases by maintaining a high pressure around the filament, the low melting point becomes a serious limitation for which no absolute remedy is in sight.

The limitations of incandescent illuminants may be changed, of course, in case a substance having a radiant spectrum lying very largely within the visible zone were discovered—in other words, one exhibiting selective radiation in a high degree while solid.

Referring again to the equation previously derived for the total quantity of energy radiated at any given frequency,—
$E = \int Ce^2w^4ndt$, and assuming, what is generally accepted,* that e is the charge upon an electron, the only variables are the frequency, the time and number of electrons involved. It follows therefore, from the expression that the maximum intensity or maximum energy radiated by each unit will be obtained with

* J. J. Thompson, Conduction of Electricity through Gases.

the highest frequency and when the greatest possible number of electrons are involved.

In solid matter the particles are too closely associated to vibrate without considerable restraint, it is evident, therefore, that to secure the effect of resonance, or selective radiation, the moving particles should be as far separated as possible. Therefore, in most cases, selective radiation is confined to gases or vapors, and the study of radiation efficiencies becomes the study of gas radiation.

From previously quoted formula, it will be noted that the quantity of light radiation varies directly with the number of electrons which are subjected to the accelerating force. Therefore, to secure the maximum intensity per unit volume of radiating gas, the pressure should be as high as possible, as this means the presence of a large number of electron groups. The mere presence of a large quantity of electrons, however, is not in itself an insurance of either a high intensity of light or a high efficiency. It is only those electrons which are subjected to a change of rate of motion (or acceleration) between certain limits which are effective as radiators. Since the acceleration of an electron sufficiently to radiate in the wave lengths included in the limits of visibility implies the acceleration of the adjacent systems to nearly the same degree, a rough measure of the efficiency of light production in a gas, will be the ratio of the number of radiating systems to the total number of such systems being acted upon. To secure a high efficiency, it is therefore desirable to use as small a quantity of gas as possible and to cause as many of the electron systems as possible to take part in the change in rate or direction of motion. In passing, it is of interest to note that the electric arc approaches this condition more nearly than other illuminants as the pressure is comparatively high and the percentage of active particles relatively large.

A chemical reaction between gases is the best known method of accelerating a large percentage of the atoms present. The percentage acted upon will, of course, be definitely determined by the phase rule, and will depend upon the rate of dissociation and of recombination at the temperatures at which the gas is worked. It is of passing interest to note that in the various types of flame

carbon arcs and metallic flame arcs advantage is taken of chemical combination to secure a high intensity, and a high efficiency. In these arcs the various cerium, titanium, or calcium compounds are heated to the temperatures at which dissociation takes place while the rapid movement of the gases carries the dissociated products to a region of lower temperatures where recombination takes place. Thus probably the majority of the constituent compounds undergo a chemical reaction at least twice which results in a considerable acceleration of the electrons, and therefore, in light production. The striking difference in luminosity of different portions of the flame arcs, and their sheath-like appearance due to the varying intensity of the light in the surrounding layers is a confirmation of this theory, the inner very hot layer being the source of relatively little radiation while the surrounding sheath which is the seat of the dissociation and recombination of the chemicals of the arc is the source of most of the light.

It seems probable that the high efficiencies of the Welsbach mantle are explainable on the same basis, namely that at the high temperatures of the gas flame, an unstable compound of thorium and cerium with oxygen or other elements is formed and that the continual formation and decomposition of this compound involves many more atoms (and thus effects many more electrons) than would be possible by merely heating the mantle. This is in part substantiated by the fact that heating the mantle in an inert atmosphere does not produce very much light. In passing it is of interest to note that the addition of thorium (which appears to be essential to the successful operation of the Welsbach mantle) does not appreciably improve the efficiency or intensity of the light from a flame carbon arc in which cerium is the chief illuminant. A possible explanation of this fact is that the function of the thorium is to lower the temperature at which the unstable compounds form, while in the flame carbon arc the temperature is sufficiently high to make this unnecessary and thus removes the advantage of thorium.

In addition to considerations of the intensities of the radiation, the position and number of the lines in the spectrum of a substance is of great importance in determining its value as a

source of light. Quite recently some convincing theories have been developed which account for the position of the spectrum lines very consistently. These theories assume that the atoms of the various elements are capable of existing in a number of more or less stable states due to the rate of motion and the number of the component electrons. In passing from one condition of stability to the next stable condition a certain amount of radiation is emitted which will have a definite wave length due to the rate of acceleration of the electrons at that instant. The various stable states can actually be demonstrated by models in which small charged spheres are arranged around a central charged sphere of opposite sign.

A mathematical analysis of the behavior of charged particles moving about a central charged particle of opposite sign results in a formula from which the calculation of the exact position of the spectrum lines can be made in the case of hydrogen and some of the simpler elements.* This theory leads to the supposition that chemical affinity is the result of electrical forces between the groups of electrons and that at the instant a change from one stable state to another stable state occurs (or at resonance) the chemical compound is destroyed. On this basis it would seem that those elements which have the greatest number of transition stages (and therefore, have the most intense and complete spectrum) are reluctant to combine with other elements and would most readily dissociate when combined. This is confirmed by experiment in that hydrogen, nitrogen, helium, argon and neon, etc. (the elements which are perhaps the least active) are peculiarly efficient as illuminants in a Geissler tube or its equivalent, while oxygen, flourine, chlorine and the so-called more active elements are relatively very inefficient as radiators and have relatively very few bright lines in their spectrum.

SUMMARY.

Summarizing the theories which have been advanced, it appears that we cannot hope to secure a radiation efficiency from known incandescent solids by simple black body radiation, which will be much greater than 5 per cent., due to the low melting points, and that therefore, the greatest expectation of obtaining

* A. Crehore, *Philosophical Magazine*, July, 1913.

a high efficiency lies along the lines of selective radiation from electrified or incandescent gases. Since the highest efficiencies will be obtained by using the minimum amount of gas and forcing the greatest possible number of electron systems to take part in the acceleration, some form of arc (or gaseous conductor) appears to be the most promising field for the future. Further, as different materials have different radiant efficiencies, the arc should be fed with materials which will give the maximum radiation within the limits of visibility, and in the proportions which produce white light. In selecting the material for supplying the radiation of an arc it should be borne in mind that chemical inertness is frequently an indication of an extended spectrum of considerable intensity.

CONCLUSIONS.

The conclusions which the facts summarized in this paper seem to indicate are, that in spite of the remarkable work which has been done, in raising the efficiency of the incandescent lamp, it is nearing its maximum theoretical efficiency. Although the fact should be kept in mind that ease of application, size of units, maintenance cost and first investment, may have as much weight in deciding upon the type of illuminant used as the absolute efficiency and, therefore, illuminants employing incandescent solids will undoubtedly have a place in the art for a considerable period. However, the vapor conductor type of illuminant, as for instance the flame arc and metallic arc, has only begun to approximate its possible efficiencies and therefore, has a very large field ahead of it.

THE PENTANE LAMP AS A WORKING STANDARD.*

BY E. C. CRITTENDEN AND A. H. TAYLOR.

Synopsis: This paper recommends the use of tested pentane lamps as secondary standards of candle-power when electric standards are not available, and gives a detailed statement of the method of testing followed at the Bureau of Standards, with general directions for the use of the lamps. The effects of variation in pentane and in atmospheric conditions are discussed, a correction for the former is proposed, new determinations of the humidity correction factor are given, and a chart is provided to facilitate the reduction of observations to normal candle-power.

INTRODUCTION.

In the TRANSACTIONS of the Illuminating Engineering Society there have already been published two papers[1] dealing with the work on flame standards of candle-power which has been done at the Bureau of Standards. These papers were intended to be particularly reports of progress in the experimental work which has been done on various types of lamps. The investigation of the lamps was made with the double purpose of determining whether any of them were capable of furnishing a check on a possible drift in the value of the unit now maintained by electric incandescent standards, and of finding a satisfactory working standard for use where electric standards are impracticable.

The results of that work proved to be distinctly favorable to the use of the Harcourt 10-candle pentane lamp as a secondary standard. Since the publication of the papers mentioned the use of such lamps has become much more extensive, and the present paper is written with a somewhat different object in view, namely, to cover the questions which have arisen regarding their operation. This involves a fulness of detail which will not be of much interest to the general reader, but which it nevertheless appears desirable to put in print because some of this information is not generally available.

* A paper read at the seventh annual convention of the Illuminating Engineering Society, Pittsburgh, Pa., September 22-26, 1913.

[1] TRANSACTIONS, Illuminating Engineering Society, Vol. V, pp. 753-778, 1910; and Vol. VI, pp. 417-432; 1911.

Extent of Use of Pentane Lamps.—The number of pentane lamps tested by the Bureau is not an exact indication of the extent to which the use of the lamps has increased, because many have been standardized in other laboratories and many others, especially in the early years of their use, were not standardized at all. Nevertheless the number tested, as given in the table below, is an indication of the widespread adoption of this standard.

PENTANE LAMPS TESTED BY THE BUREAU OF STANDARDS.

1908	4
1909	6
1910	7
1911	17
1912	35
1913 (6 months)	15
Total	84

Since in many cases one of these lamps furnishes the basis on which the quality of the gas supply of a city, so far as candle-power is concerned, is judged, the importance of the pentane lamp in present practise will be appreciated.

POSSIBLE USES OF PENTANE LAMPS.

While the lamp has found its widest use in gas testing, where a flame standard is preferred because the effects of atmospheric conditions on it compensate for similar effects on the gas flame, its usefulness is by no means limited to work of that kind. The corrections to determine the actual candle-power are easily made, and the lamp affords a fairly convenient method of obtaining a basic standard for laboratories which lack the batteries and accurate instruments which are necessary to get reliable values from electric standards.

In some cases the pentane lamp may thus serve as a basis of standardization even when it may be found more convenient to use other standards for the actual tests. For example, when a series of measurements are made extending over several hours, another source such as a kerosene lamp, an Edgerton standard or a gas mantle may be used as a constant comparison light at one end of the bar, its value being fixed by substituting a pentane lamp for the test flame or lamp at the beginning and the end of the series. An electric lamp kept at constant current may be

used in the same way as a comparison light. This is exactly what is done in most portable photometers, and the calibration of such photometers can be based on a pentane lamp as well as on an electric standard. A modification of this practise which is useful where tests for approximate values have to be made at a number of stations is to provide for each station a portable standard unit consisting of a low voltage lamp and a storage battery, the whole unit being brought in at regular intervals for recharging and recalibrating against the pentane standard. From a curve showing the variation in candle-power with time of use for such a unit one can obtain fairly satisfactory values without the use of either regulating resistances or electrical measuring instruments. The details of such a system in actual operation are given by Mr. H. L. Farrar, in the *Gas Age* of April 15, 1913 (pp. 407-409). In using such standards, as in any case where electric lamps are compared with flames, the effects of humidity are important. The readings can, however, be easily corrected for this by the use of such a chart as is given in Fig. 3.

It is hardly necessary to give here a long discussion of the relative advantages of different lamps, and of the reasons which are leading to the common use of the pentane lamp as a working standard in this country. There are other lamps which may be used in cases where their value can be frequently checked or where the accuracy required is not great. In some other cases, especially where portability is an important consideration, the Hefner lamp is to be recommended; by making many measurements under favorable conditions very good results can be obtained with it, but in general its low candle-power, comparatively red light, extreme sensitiveness to drafts, and unsteadiness at temperatures above 70 deg. F. make it difficult to use. The pentane lamp has the disadvantages of being large and not easily portable, of using fuel which is expensive and somewhat dangerous, and of requiring more air than ordinary ventilation will supply. In spite of these faults its use is increasing, chiefly because it appears to be the only standard of candle-power now in use, other than incandescent electric lamps, which can be relied upon to give under the usual working conditions the degree of accuracy expected in present commercial practise.

STANDARDIZATION OF LAMPS AT BUREAU OF STANDARDS.

NECESSITY OF PHOTOMETER TEST.

The necessity for standardization of each lamp by a photometric test arises from the fact that different lamps, even of the same maker and supposedly of the same type, show differences in candle-power which are sometimes as great as 4 per cent. The construction is such as to make it difficult to determine after a lamp is assembled whether it is built exactly according to specifications. In fact, exact adherence to specified dimensions might not remove the differences between lamps unless other conditions also were definitely specified. For example, the castings used in the American lamps have a rough inner surface; this roughness probably facilitates the transfer of heat to or from the air, and it may also affect slightly the flow of air through the passages. Whatever may be the cause of the differences between lamps, the candle-power of the individual lamp is the important thing, and hence the logical test to make is a determination of the candle-power. In lamps tested at the Bureau details of construction are not given special attention unless some part is so made that it appears to be a possible cause of variation in the candle-power of the lamp.

Since the lamp itself is only an instrument for producing the actual standard, the flame, there is little significance in a value given for the lamp unless other factors, such as air and fuel and other conditions of operation, are known. The value certified for a lamp applies strictly only for its use under conditions identical with those under which it was standardized; it may therefore be worth while to particularize rather fully the method of testing followed at the Bureau.

PHOTOMETER ROOM.

The photometer room used hitherto is approximately 26 x 18 x 12 feet (7.92 x 5.49 x 3.66 m.). Ventilation is obtained by a tempered air heating system. The ordinary ventilation would not keep the air sufficiently pure if the flame gases were allowed to escape into the room, and consequently above the lamp is hung a hood 2 feet (0.6 m.) in diameter with an outlet into one of the ventilating ducts. The draft into this hood is just strong enough

to ensure that all the gases rising from the lamp shall pass into the hood and thus be carried out of the room. This arrangement is so effective that no perceptible change in the candlepower of the lamps due to vitiation of the air occurs in several hours continual burning. In regular work, however, the room is usually aired out at least once every hour.

The photometer room is in a corner of the building and often has troublesome drafts, in consequence of which it has been found that the performance of the lamps has been improved by screening them on three sides and sometimes on all four sides. This is done by a wooden frame-work about 3 feet (0.91 m.) long, 2 feet (0.61 m.) wide and 3 feet (0.91 m.) high, carrying a strip of cloth which extends from the top of the frame down to 6 inches (15.24 cm.) from the bottom, thus allowing free access of the air from all sides below the lamp, but preventing any drafts from striking the flame or the circulatory system of the lamp directly. This screening was adopted after many trials of various forms of enclosure had shown that in most of them the lamps gave values slightly different from those obtained in the open, even when no vitiation of the air in the enclosure could be detected.

In special tests of the state of the air a Zeiss refractometer has been used to determine the quantity of CO_2 present. Measurements of atmospheric moisture are regularly made with 2 Assmann psychrometers, and of pressure by a mercury barometer. The details of the calculation of the moisture will be given later in connection with the corresponding corrections.

The photometer outfit is of the standard form regularly used at the Bureau, with Lummer-Brodhun contrast head and a recording device which has been described in the *Bulletin* of the Bureau.[2] The substitution method with constant intensity on the disk is used as in all standard work, that is, a constant "comparison lamp" is connected to the photometer head at a fixed distance from it, while the electric "working standards" and the pentane lamps under test are alternately put in on the other side for reading.

[2] G. W. Middlekauff, Bulletin B. S., 7, p. 18, 1910. Reprint No. 144, and *Electrical World*, Vol. LVI, p. 153, (July 21) 1910.

ADJUSTMENT OF LAMPS.

Before putting the lamp on the photometer the chimney is inspected by looking down through it to see that it is set centrally over the burner, and each time the lamp is lighted the gauge is applied to make sure that the chimney is at the proper height, that is, 47 mm. above the burner when cold. The chimney seldom has to be reset, but occasionally one creeps slightly with heating and cooling.

In setting up the lamp on the table care is taken to level it so that the chimney shall be vertical. The levels (plumb bobs on later lamps) attached for this purpose are not always exact, and this leveling is done by dropping a plumb line from the center of the top of the chimney so that the bob should hang centrally in the burner. The height of the lamp is so adjusted that the middle of the flame is on a level with the center of the photometer disk. The directions of the Gas Referees are such as to bring the bottom of the chimney on a level with the center of the disk, and this setting makes the illumination on the disk follow the inverse square law more exactly than if the lamp is higher. The American Gas Institute's Committee on Taking Candle-power of Gas has, however, recommended the other position and in order to avoid confusion the Bureau has followed this recommendation. The lamp is usually placed so that the line of the bar passes through the lamp standard as well as through the center of the burner and chimney. In some cases, however, on request, the lamps are turned 90 deg. so that a plane passing through the chimney and the standard is at right angles to the line of the bar. No difference has been detected in the values obtained in the two positions for any lamp. In either case the chimney is so turned that the light from the mica window does not fall on the photometer disk or on the lamp standard or the pentane feed tube.

In measuring distances from the lamp the center of the burner is taken as the point of departure. The photometric observations are made at a distance of approximately 1 meter. For setting the lamp at the proper point on the scale it has been found convenient to follow the English method of using a rod having near one end a cylindrical plug which fits into the burner.

This rod is made of such length that the other end just touches the photometer head when the center of the burner is one meter from the disk. This fixes very exactly the point of the scale which is 1 meter from the lamp, and a line on the record sheet is set at this point. The distance of the comparison lamp is then so chosen as to make the settings on the pentane lamp fall near the line, and in working up the sheet the distances of the groups of points which represent readings on the lamp are measured from this line.

OPERATION OF LAMPS.

Pentane.—The pentane used is tested with respect to density and purity; the effects of possible variation in the fuel are so important that a later section of this paper is devoted particularly to that question.

Flame Height.—The method of controlling the flame height has been the subject of considerable difference of opinion. At the Bureau no difference in candle-power has been found to result from the use of the various cocks at which regulation may be effected. Even when the saturator is entirely closed off from the air, and the pressure of the vapor in it is allowed to run up to 9 inches (29.53 cm.) of water, regulation of the flame height being made by a cock near the burner, no departure as great as 1 per cent. from the normal candle-power occurs. In standardizing the older lamps, in which such cocks are provided, they have been used. The newer lamps do not have these cocks, and flame height is controlled by the outlet cock of the saturator, in which case greater ease of adjustment is obtained by clamping a lever on to the handle of the cock.

Another question concerning which there are differences of opinion is that of the proper flame height. In English lamps the top of the flame should be set at the middle of the lower mica window, about 27 mm. above the bottom of the chimney. The lamps are so proportioned that this height of flame gives a maximum candle-power and a small shift up or down makes very little change in candle-power. This is shown in curve E of Fig. 1 where abscissas are candle-powers and ordinates are heights of flame in the chimney. The effect of personal error in judgment of height of flame is thus made very small.

The American makers have placed the crossbar of the window lower, and direct that the flame be set with the tips at the top of the bar, which is about 22 mm. above the bottom of the chimney. As is shown in curve A of Fig. 1 this is not high enough to give the maximum candle-power, and at this height small changes cause relatively large variation of candle-power.

At the Bureau it has been considered important to retain the advantage given by using the maximum candle-power, and incidentally to adhere to the original manner of operating the lamps. The practise has therefore been definitely adopted of first determining the height of flame which gives the maximum candle-

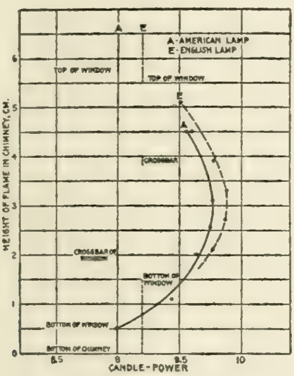


Fig. 1.—Variation of candle-power with pentane lamp, with height of flame.

power for a given lamp, and then standardizing the lamp with the flame at that height. With American lamps the maximum is usually obtained when the top of the flame is about a centimeter above the bar. A line is marked on the window to show the height used, and the fact is stated in the certificate furnished with the lamp.

Time of Burning.—The necessity of waiting a sufficient time after lighting the lamps before making measurements was emphasized in the earlier papers where curves were given showing the variation of candle-power with time after lighting for English and American lamps. It is important to note that the candle-power rises rapidly at first, going above the normal, and then settles back to a fairly constant value. Considerable attention

has been given to the measurement of the variations in temperature in various parts of the lamp which accompany these changes in candle-power. The details of the measurements will not be given here, but it may be said that they have strengthened the conviction that most of the change in candle-power caused by variation in conditions of operation may be attributed to the air circulating system and the variations in the flow of air which arise from changes in the relative temperatures of parts of the lamp. There is a slow change of temperature for a considerably longer time, but the candle-power is practically constant after 30 minutes in the case of the old style American lamps and after 20 minutes with the newer lamps. The excess of the maximum over the final candle-power is about 3 per cent. and 2 per cent. respectively for the two types. Lamps of the English type run from 1 to 1½ per cent. high at the maximum and may be considered constant after 15 minutes burning. The smaller heat capacity of these lighter lamps, which allows them to reach a steady state sooner, seems also to make them more susceptible to variations caused by changing drafts.

BASIS OF STANDARDIZATION.

The fundamental unit in terms of which lamps are certified is the international candle[3] as maintained by the primary electric standards of the Bureau. The standards actually used in tests are a group of 7 carbon lamps operated at low voltage so as to match the pentane in color. Since the flame is much redder than the ordinary electric standards the calibration of these special standards has taken considerable labor to insure that no important error be introduced because of this color difference. The group has been compared with the Bureau's regular working standards in three series of measurements with a number of different observers, under the direction of Dr. Middlekauff, and the average values have been as follows:—

	Candle-power
1911	4.98
1912	4.98
1913	4.97

It appears therefore that the uncertainty in the value of these

[3] Bureau of Standards, Circular No. 15.

standards cannot be very great. As a check on their permanence another group carefully compared with them is preserved and used only for checking the working standards. A similar group has also been prepared to be sent to England in order to obtain a direct comparison between the standards of the National Physical Laboratory and those of the Bureau at pentane color.

To obtain the normal candle-power of the flame, corrections are made for the effects of atmospheric moisture and pressure. These corrections will be considered in a separate section since they must be used whenever it is desired to obtain absolute candle-power values with a flame standard. As a check against the introduction of errors by other conditions, such as poor ventilation, which might affect the flames but not the electric standards, a pentane lamp of known candle-power is always included in tests.

NUMBER OF MEASUREMENTS.

The number of measurements made on each test lamp in the course of standardization depends somewhat on the consistency of the results obtained. Usually each lamp is placed on the photometer about six times, and each time four groups of sets are made, each group consisting of 25 to 40 settings of the photometer. The candle-power result for each group is worked up separately, and if the average deviation of these values from the final mean is not materially greater than one-half per cent., and the values obtained for the check lamp run in the test are also normal, the test is considered satisfactory. If these conditions are not fulfilled, further measurements are made until it is believed that the mean candle-power of the lamp is sufficiently well determined. The candle-power is certified to the nearest tenth of a candle unless the average of test results falls very nearly half way between tenths, in which case a subscript 5 is given in the hundredths place; this is written as a subscript to indicate that it is not considered as definitely established, but merely as representing the average of test results.

ACCURACY OF VALUES.

With all the precautions taken it is believed that the values certified for the lamp are correct within one per cent., that is,

that under similar conditions the lamps should give average results within one per cent. of those certified. It has occasionally happened that a second test on a lamp has given a result fully one per cent. different from the value originally certified. The result obtained from a single time on the photometer sometimes departs as much as 2 per cent. from the mean, but the maximum deviation is seldom as great as this. As for the permanence of the calibration no evidence has been obtained indicating any appreciable change with time. For the Bureau's two Chance lamps which are regularly used as checks on tests the average candle-powers found in 1910 were 9.87 and 9.89; the averages for the first six months of 1913 have been 9.90 and 9.87.

Conditions in different laboratories are not likely to be exactly the same, and in order to depend on reproducing values in different places as closely as one per cent. one would probably need to give some care to reproducing conditions of operation. It would seem, however, that under any reasonably good conditions the difference ought to be well within 2 per cent., for, using good pentane and correcting for atmospheric moisture and pressure, it is difficult to produce that much variation in candle-power by any intentional change of conditions except vitiation of the air or incorrect flame height.

GENERAL DIRECTIONS FOR USE OF PENTANE LAMPS.

It is hardly practicable to give here detailed directions as to the exact procedure to be followed in any case, but attention may be called in a general way to some precautions which should be taken in using the lamps. Many of the details of adjustment and operation which have already been discussed will be merely mentioned here. The best results will presumably be obtained by following the same methods in operating a lamp as were used in standardizing it. If the lamp to be used has been standardized at the Bureau a reference to the preceding pages will answer most questions as to proper procedure. If the value of the lamp has been assigned by another laboratory such questions should usually be referred to that laboratory.

VENTILATION AND EFFECTS OF VITIATION OF AIR.

Since all flames depend upon combustion it is to be expected that their intensity will vary with the proportion of oxygen and of other constituents in the air supplied to the gaseous fuel of the flame. To maintain a flame in a constant condition requires, therefore, not only uniform fuel, but also a uniform proportion of oxygen in the air supplied to the flame. Good ventilation is consequently desirable for all work with flames, and is indispensible where lamps of other kinds are to be compared with a flame standard. The quantity of air which must be supplied depends largely on the size and number of flames in the room and also on the method of ventilating. The flames themselves set up currents of air, and if possible these currents should be utilized to remove immediately from the room all the vitiated air coming from the lamps. A hood placed above the photometer with a rising pipe to lead the warm air out of the room is most effective.

If the gases from the flames are allowed to diffuse into the room and are simply diluted by the air entering, a much larger amount of fresh air will be needed. In such a case it has been estimated[4] that to keep the carbon dioxid content of the air down to six parts in 10,000, 3,000 cubic feet (84.95 cu. m.) of fresh air per hour must be supplied for each person in a room. A committee of the American Gas Institute[5] has on this basis estimated that 36,900 cubic feet (1045 cu. m.) of air per hour should be supplied for a photometer room where two persons work with a pentane lamp and a 5-foot (141.6 l.) gas flame, since in the production of carbon dioxid the gas flame is approximately equivalent to 6 persons and the pentane lamp to four.

In a room where air enters at the bottom and escapes at or near the top, the quantity estimated as above (about 12,000 cubic feet (340 cu. m.) per hour for a pentane lamp) is probably ample for any purpose, and if care is taken to allow direct escape of the flame gases a much smaller amount is sufficient.

Some caution is necessary in making calculations based on the quantity of carbon dioxid in the air. Experimental determina-

[4] Kent, Mech. Eng. Pocketbook; 1912 Ed., p. 654.

[5] *Proceedings American Gas Institute*, Vol. II, pp. 481-482, 1907.

tions of the effect on flames have sometimes been made by adding carbon dioxid to the air, and it must be remembered that the dilution of the air by a quantity of added CO_2 has relatively little effect as compared with the conditions arising when the same amount is formed in the process of combustion, using up the oxygen of the air. In the formation of five cubic feet of CO_2 by the combustion of pentane, for example, 8 cubic feet of oxygen are used. Since the abstraction of 1 cubic foot of oxygen has practically the same effect on the composition of the air as the addition of 5 cubic feet of inert gas, it is evident that the reduction in the amount of the active oxygen is of much greater importance than the increase in the diluting gases. The effect produced on the Hefner lamp by adding one part of CO_2 to 1,000 of air, according to Liebenthal,[6] is a reduction of 0.7 per cent. in the candle-power, but the generation of the same proportion of CO_2 by combustion and breathing in a room has been found[7] to be accompanied by a decrease of 2.2 to 3 per cent. in the Hefner, the pentane lamp and other flames. In general the effect depends on the manner of production of the CO_2, since the greater part of the decrease is due not to the presence of CO_2 but to a deficiency of oxygen. Determinations of the amount of CO_2 in the air consequently do not furnish sufficient data for exact correction for vitiation of the air, but are useful in that they enable one to judge the effectiveness of the ventilation.

In many cases, however, determinations of CO_2 are not practicable and the effectiveness of the ventilation must be judged by other means. When facilities are available for setting an electric lamp repeatedly to the same current a direct test can be obtained by making a series of measurements of the electric lamp against the pentane and finding whether the latter shows a gradual decrease after it should have reached a constant value. Another test which is as definite as determination of the carbon dioxid and far more easily carried out is afforded by careful measurement of the humidity, for the processes which use up

[6] *Zeitsch. f. Instrumentenkunde*, Vol. XV, p. 157, 1895.

[7] C. C. Paterson, Collected Researches, National Phys. Lab., Vol. III, p. 49, 1908.

Butterfield, Haldane & Trotter, *Journal Gas Lighting*, Vol. CXV, p. 290, 1911, and *American Gas Light Journal*, Vol. XCV, p. 145, 1911. Also unpublished tests of Bureau of Standards.

oxygen add water as well as CO_2 to the air. If the water vapor regularly increases by an appreciable amount during the operation of the lamp the ventilation is not satisfactory. An increase of one liter of water vapor per cubic meter of air, when caused by poor ventilation, is quite regularly accompanied by such vitiation as to cause about 2 per cent. decrease in the candle-power of flames, in addition to the 0.6 per cent. decrease caused by the water vapor itself.

In designing ventilating inlets ample capacity should be provided to allow a slow flow of air into the room in order to avoid drafts which would cause unsteadiness of the flame. Similarly if a hood is used as recommended the outlet must be so arranged that the flow of air into the hood shall not be too vigorous. Troublesome drafts are apt to arise if the walls of the photometer room differ much in temperature from the air. It is therefore desirable that none of them shall be exterior walls of the building. If such walls are unavoidable they should be either jacketed with non-conducting material or covered by a false wall with an air-space. If possible the room should be so free from drafts that the flame will burn steadily without other protection than the necessary photometric screens. If further protection from drafts is necessary a screen of the form described on a preceding page should be used.

PREPARATION OF LAMP.

In preparing the lamp for use one should observe the following details: centering of chimney over the burner, height of chimney above the burner, direction in which the mica window is turned, amount of pentane in the saturator, height, orientation and leveling of the lamp, and its distance from the middle point of the bar or some other definite point on the scale. It is advisable, at least in the beginning, to check the last two adjustments by direct measurement previously described. If then the plumb bobs (or the level and bob) are found to be correct they may be used thereafter.

The saturator should be from one-third to two-thirds full of pentane at starting, and the height of the liquid as seen against the window of the saturator should never be less than ⅛ inch (3.175 mm.). Since pentane is very volatile and inflammable,

and the heavy vapor flows downward, it is extremely hazardous to fill a lamp while it is burning. This should never be attempted under any circumstances, and it should be an inviolable rule of the laboratory that no pentane in an open vessel be brought near any flame.

OPERATION.

Immediately before the lamp is lighted the height of the chimney should always be tested with the gauge, and occasionally the gauge itself should be measured to see that it remains 47 mm. long. To light the lamp open first the saturator inlet cock; then holding a lighted match over the burner open the outlet cock gradually. If the lamp has a regulating cock near the burner, the saturator cocks may both be opened and the flame controlled by this regulating cock. If no such cock is provided the saturator outlet cock is used for regulation. Usually on opening the cocks the vapor will flow so that the lamp will light, but it is sometimes necessary to start the flow of vapor by blowing gently into the saturator inlet. Sometimes also the lamp at first burns with a small blue flame because the heavy vapor has flowed down into the burner and prevents the normal circulation of air from starting. If this happens shut off the cocks, and blow up into the outer chimney to start the air, keeping below the burner to avoid the small burst of flame which may result if the flame has not entirely died out in the tip. The lamp will then light normally. After it is lighted see that the conical hood around the flame is so placed that the whole flame is visible from the photometer disk.

The flame should be kept at approximately the correct height, and no measurements should be made till the lamp has burned 15, 20, or 30 minutes according to whether it is of the English type or of the new or old American forms. Unless otherwise specifically stated in the lamp certificate for the American lamps the proper flame height is obtained when the tips are just above the crossbar of the window, while in English lamps the flame should extend half-way up the lower window. As already stated American lamps standardized recently at the Bureau of Standards have a line on the window to which the top of the flame is to be set. After the lamp has burned a few minutes such changes in

flame height as occur are gradual, and except in the most careful work it is not necessary to have a special observer to watch the flame.

The lamp is extinguished by shutting off the saturator cocks. When it is not in use both cocks should be kept closed and a cap should be placed over the burner to prevent injury to it or the collection of dust in the passages. All parts of the lamp should be kept well blackened.

PENTANE: PREPARATION, TESTING AND USE.

The directions of the Gas Referees for the preparation and testing of pentane are as follows:

Preparation.—Light American petroleum, such as is known as Gasoline and used for making air-gas, is to be further rectified by three distillations, at 55 deg. C., 50 deg., and 45 deg. in succession. The distillate at 45 deg. is to be shaken up from time to time during two periods of not less than 3 hours each with one-tenth its bulk of (1) strong sulphuric acid, (2) solution of caustic soda. After these treatments it is to be again distilled, and that portion is to be collected for use which comes over between the temperatures of 25 deg. and 40 deg. It will consist chiefly of pentane, together with small quantities of lower and higher homologues whose presence does not affect the light of the lamp.

Testing.—The density of the liquid pentane at 15 deg. C. should not be less than 0.6235 nor more than 0.626 as compared with that of water of maximum density. The density of the pentane when gaseous, as compared with that of hydrogen at the same temperature and under the same pressure, may be taken. This is done most readily and exactly by Gay Lussac's method, under a pressure of about half an atmosphere and at temperatures between 25 deg. and 35 deg. The density of gaseous pentane should lie between 36 and 38.

Any admixture with pentane of hydrocarbons belonging to other groups and having a higher photogenic value, such as benzene or amylene must be avoided. Their presence may be detected by the following test. Bring into a stoppered 4-oz. bottle of white glass 10 cc. of nitric acid, specific gravity 1.32 (made by diluting pure nitric acid with half its bulk of water); add 1 cc. of a dilute solution of potassium permanganate, containing 0.1 gram of permanganate in 200 cc. Pour into the bottle 50 cc. of the sample of pentane, and shake strongly during five successive periods of 20 seconds. If no hydrocarbons other than paraffins are present, the pink color, though somewhat paler, will still be distinct; if there is an admixture of as much as 1/2 per cent. of amylene or benzene, the color will have disappeared.

For the benefit of those who are not chemists it should be said that this last test should always be preceded by a blank test to

check the purity of the reagents, for if the nitric acid is not pure it will decolorize the permanganate. The acid should be kept in the dark to avoid deterioration.

The pentane used at the Bureau is tested with respect to purity and density of the liquid. The density is conveniently determind by a hydrometer carrying a thermometer. The correction for temperature is important, being about 0.001 per degree Centigrade or 0.00055 per degree F. In the sealed ether cans in which pentane is now purchased no difficulty has been found in keeping a supply which fulfills the specifications when the cans are opened, but the more rapid evaporation of the lighter fractions raises the density as the fuel is consumed in the lamp. It is quite impracticable to work with pentane within the limits prescribed, for the density is certain to be too high before one-tenth of the pentane is consumed; in fact the density usually reaches 0.635 when a little over half has been used.

CORRECTION DETERMINED BY DENSITY.

The directions of the London Gas Referees are to empty the saturator completely at least once a month when three tests daily are made, but this appears to be decidedly too long a period. The residue of higher density gives a slightly higher candle-power than the fresh pentane. When repeated additions of fresh fuel are made, and the accumulated residue remains in the lamp, a mixture is obtained such that an appreciable change in candle-power may occur in a relatively short time. It therefore appears desirable to empty the saturator after it has been replenished only three or four times. It is not necessary, however, to discard the portions emptied out; if these are collected and not mixed with fresh pentane, fairly reliable results can be obtained by using the residues thus collected, making a suitable correction determined by the density. Considerable attention has been given to the determination of such a correction, and the results of the measurements made are shown in Fig. 2. The relation between candle-power and density is probably not really linear, but for present purposes may be assumed so. It will be seen that the change in candle-power averages about 1 per cent. for an increase of 0.01 in the density of the fuel. Samples of pentane from different sources which have been initially high in density have also given

results agreeing fairly well with this rule. Consequently it appears to be allowable to apply such corrections in many cases where the expense for pentane can thus be cut down materially without any considerable sacrifice of accuracy.

In the standardization of lamps at the Bureau the pentane used is always kept below 0.635 in density. The values certified may therefore be considered as correct for a density of 0.630. No correction need be made for pentane below 0.635, but above that density correction is desirable. For example, if the pentane used runs up to 0.650 the candle-power obtained is presumably 2 per cent. above that certified for the lamp, and this density is likely

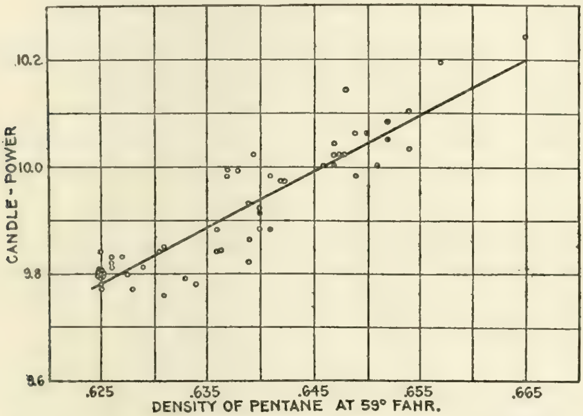


Fig. 2.—Effect of pentane density on candle-power of pentane lamps.

to be reached if a gallon of pentane is used without removing the residue from the saturator.

It should be noted that the above discussion refers to pentane which is initially fairly pure, as shown by the permanganate test. If the fresh pentane contains impurities these are usually concentrated by the fractional distillation in the lamp, and the result may be an increase in candle-power greater than that given above.

EFFECTS OF ATMOSPHERIC CONDITIONS.

It is usually assumed that the effect of all atmospheric conditions is the same on all flames, and is therefore automatically corrected when flames are compared with flames, but it is sometimes necessary to know the amount of departure from the

normal value, as when flame standards are compared with electric lamps. The dependence of flame intensity on the composition of the air is so complicated a matter that the determination of exact corrections for vitiation of the air is impracticable, and when observations are to be reduced to normal values good ventilation is indispensable so that no such corrections shall be needed. With pure air, however, there are considerable variations in candle-power because of variations in the amount of moisture and in the barometric pressure.

TEMPERATURE.

Temperature might also be expected to affect the pentane lamp appreciably, but nearly all investigators have agreed that within the usual laboratory range it does not do so. In the work at the Bureau there has so far been available no means of changing temperature and humidity independently, and the effects of the two cannot be separated with certainty. The results obtained can be represented about equally well by assuming that temperature has no effect or by making a small correction for temperature and using a correspondingly different factor for water vapor. In accordance with the usual custom the former practise will be followed, and the present discussion will be limited to the effects of barometric pressure and of water vapor.

BAROMETRIC PRESSURE.

In general, flames give less light when the barometric pressure is low, but the effects on different sorts of lamps are markedly different. For the 10 candle-power pentane lamp a change of 0.6 per cent. per cm. (1.5 per cent. per inch) was found at the German Reichsanstalt,[8] while the result obtained at the English National Physical Laboratory[9] is 0.8 per cent. per cm. (2 per cent. per inch), and more recent work[10] in England has verified the latter value for pressures near the normal. Various determinations at the Bureau have not been consistent, chiefly because of the small range of pressure obtained. The results for the determinations which should have been most reliable have

[8] *Jour. fur Gas. u. Wasser.*, Vol. XLIX, p. 561, 1906.

[9] *Electrician* (London), Vol. LIII, p. 571, 1904. *Journal Institution of Electrical Engineers*, Vol. XXXVIII, p. 271, 1906-7. *Journal Gas Lighting*, Vol. XCIX, p. 232, 1907. N. P. L. Collected Researches, Vol. III, p. 49, 1908.

[10] Butterfield, Haldane, and Trotter, *Journal Gas Lighting*, Vol. CXV, p. 290, 1911, and *American Gas Light Journal*, Vol. XCV, p. 145, 1911.

varied from 0.6 to 0.8 per cent., and consequently the English value, 0.8 per cent. per cm. has been used.[11] The chart of deviations given in Fig. 3 is plotted on this basis.

WATER VAPOR DETERMINATIONS.

Water vapor in the air lowers the intensity of the flame; the effect has been found to be proportional to the amount of water present. This amount is expressed in liters (l) of water vapor per cubic meter of dry air, in other words in parts of water

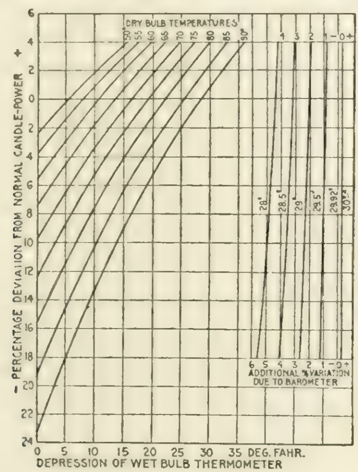


Fig. 3.—**Variation of candle-power of pentane lamps with humidity and barometric pressure.**

vapor per 1,000 parts of dry air. The pressure (e) of the water vapor is determined by means of a hygrometer (preferably of the ventilated type) using tables adapted to the particular type of hygrometer. If the barometric pressure is represented by b,

$$l = \frac{e}{b - e} \times 1{,}000.$$

A normal value (n) for the amount of water vapor must be chosen more or less arbitrarily. Then if I_n is the normal intensity of a given flame (that is, the intensity when there are n liters of water vapor per cubic meter of dry air), the intensity I at any particular time is given by the equation.

$$I = I_n \left[1 + (n - l)\, a\right].$$

[11] In the TRANSACTIONS of the Illuminating Engineering Society, Vol. V, p. 776, 1910, it was inadvertently stated that the factor 0.6 is used, when it should have been said that this factor was obtained from the data then reported on.

The normal proportion of water vapor has been fixed at 8.0 liters for the pentane lamp; the correction factor a has been several times determined, but the agreement between results in different laboratories is not close. These determinations were rather fully discussed in one of the earlier articles mentioned[12]; it is sufficient to recall here that the National Physical Laboratory[13] found a to be 0.0066, whereas the Reichsanstalt[13] obtained 0.0055 and the Bureau of Standards 0.0057. The more recent English tests[13] have given 0.00625.

The method of testing lamps at the Bureau furnishes continual data for the redetermination of the correction factor, and complete calculations have been made using the results up to the beginning of the present year on all lamps whose tests have included a range of 5 liters of water vapor or more. To reduce the labor of calculation the values obtained each time a lamp is placed on the photometer have been grouped together. Some insignificant changes in the data published in 1910 have been made to correct for slight errors introduced by the barograph then used, and the revised results are given in Part I of the table. These data include 628 groups of sets, or about 30,000

WATER VAPOR CORRECTION FACTORS.

(I.—Observations of 1910.)

Lamp	Times on photometer	Factor a	Weight
Chance 116	74	0.00568	174
Chance 118	23	0.00565	22
Sugg 171	62	0.00565	130
American 25	16	0.00584	11
American 74	19	0.00564	48
American 157	11	0.00581	8
American 162	7	0.00572	9
Weighted mean value of a		0.00567	

(II.—Observations of 1911-1912.)

Lamp	Times on photometer	Factor a	Weight
Chance 116	135	0.00586	226
Chance 118	177	0.00552	339
25 other lamps	264	0.00569	269
Weighted mean value of a		0.00567	

individual settings of the photometer. The data obtained from later tests are summarized in Part II of the table; they represent

[12] TRANSACTIONS Illuminating Engineering Society, Vol. V, p. 766, 1910.
[13] loc. cit.

about 2,300 groups of sets or perhaps 75,000 individual photometer settings. In assigning weights to individual lamps allowance was made both for the number of times on the photometer and for the range of humidity covered. Since ranges as small as 5 liters were included, giving a total variation of only 3 per cent. in these cases, and some of the lamps were on the photometer only six times, the results from individual lamps cannot be expected to agree very closely. However, only two lamps gave a value for a below 0.0050 and the highest value obtained was 0.0066. The mean result checks the former one even more closely than could be expected, and there seems to be no room for doubt that, at least in the Bureau laboratory, the effect is very definitely and consistently represented by a factor of 0.57 per cent. per liter of water vapor. This factor has been used in plotting the chart which is reproduced in Fig. 3.

This chart has been so plotted that the departure of a lamp from the normal value can be read directly from it when the barometric pressure and the readings of the wet and dry bulb thermometers of a ventilated hygrometer are known. The hygrometer may be either a sling psychrometer such as is used by the U. S. Weather Bureau or a mechanically ventilated instrument like the Assmann psychrometer. If an ordinary stationary hygrometer is used the covering of the wet bulb should be only one thickness of very thin material and the reading should be taken at the lowest point to which it can be brought by vigorous fanning.

The curves at the left of the chart give the percentage deviation from normal candle-power which corresponds to given temperature and wet bulb depression when the barometric pressure is normal, which for the pentane lamp is 760 mm. When the pressure is different from this the additional deviation can be found from the curves at the right as follows: First read off the deviation in the regular way as if the barometer were normal, and note this; then from this point pass horizontally across the sheet to that curve at the right which represents the actual pressure. Vertically above or below the point at which this curve is reached will be found the amount to be added to the deviation as read from the first curves. This added amount is made up

chiefly of the direct effect of pressure on the candle-power, but it includes also a proper allowance for the fact that the amount of water vapor which corresponds to a given pair of bulb readings depends somewhat on the barometric pressure.

The chart is plotted for the pentane lamp, but so far as we know it may be applied to other flames without introducing serious errors. It would certainly be justifiable to measure gas flames, for instance, with electric standards and to correct the observed candle-powers to obtain normal values according to the chart.

In order to give some idea of the amount of variation in water vapor which occurs from season to season, data calculated from the records of the Weather Bureau which give the state of

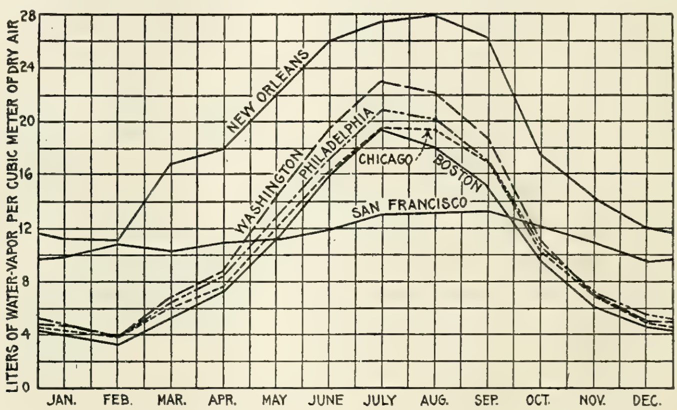


Fig. 4.—Average water-vapor content of the air at various American cities (1904 to 1908).

the out-door air have been plotted in Fig. 4. In general the amount of moisture is small in winter and large in summer; the average for May and for October is practically the same as for the whole year. The variation from day to day is often great, especially in the spring and fall, but the monthly averages show considerable regularity from year to year. The curves are plotted from the averages of observations for 5 years.

The normal values adopted in Europe are lower than the average for nearly all parts of the United States; consequently the average of uncorrected candle-powers of flame standards in this country runs somewhat lower than the normal intensities.

The following table gives the average amounts of water vapor at several cities for the period of 5 years plotted in Fig. 4. The last column gives the corresponding departure of a pentane lamp from its normal value, which is practically the percentage of difference between the nominal and the actual average candle-power of any source which is measured by the lamp.

AVERAGE WATER-VAPOR AND PENTANE CANDLE-POWER IN THE UNITED STATES.

Place	Average water-vapor Liters per cm.	Per cent. departure of pentane lamp from normal value
Boston	9.9	—1.1
Omaha	10.3	1.3
Chicago	10.6	1.5
Philadelphia	11.2	1.8
San Francisco	11.3	1.9
Washington	12.0	2.3
New Orleans	19.1	6.3

SUMMARY.

In this paper we have attempted to describe fully the method of testing pentane lamps at the Bureau of Standards, to give brief general directions for the use of the lamps, to discuss more fully the question of fuel, and to furnish data on the effects of pressure and moisture in a form which may be useful to those who have occasion to reduce observations on flames to normal candle-power values. Such new data as has been introduced has been obtained in the laboratories of the Bureau, and our acknowledgements are due to Dr. Rosa, under whose direction the work has been carried on, and to Mr. G. J. Schladt, who has assisted in most of the tests.

DISCUSSION.

MR. C. O. BOND: We are very fortunate indeed to have another study, or a continued study, of the pentane lamp from the Bureau of Standards. There are three things brought out in this paper that I would hardly have suspected, yet I have learned that when the Bureau of Standards speaks, it is dangerous to hold opposite opinions on the subject unless extremely one is well fortified, because they investigate very thoroughly.

On the ninth page it is stated that the conviction has been

strengthened "that most of the change in candle-power caused by variation in conditions of operation may be attributed to the air circulating system and the variations in the flow of air which arise from changes in the relative temperatures of parts of the lamp." In the laboratory with which I am connected we have tried to study the effect of changing the temperatures of parts of the lamp and could not arrive at very definite formulae. We knew that we did get variations in lamp values depending on whether these different parts were changed in temperature. For instance, we had one lamp that was mounted on the tripod with a solid rod supporting it, and another one with a hollow rod supporting it, and we got two different values, apparently depending on the fact that one rod was a better conductor than the other one. By abstraction of heat they would work in such a way as to change the flow of the hot air which leads to the inner part of the flame, and hot air determines the degree to which the pentane flame shall bulge. In this way the air changes the area of the flame and consequently its candle-power. Where a booth is built around a lamp, I would have expected to see some change in the flow of air at least as supplied to the flame exterior and that this would have an effect in changing the candle-power of the lamp.

The second point is in regard to the change in pressure in the saturator box. We were fixed in our belief that we did get a considerable change, although it must be said here that the largest changes came when we were using a regulating valve placed near the burner. The lamps stand some thirty inches high and the regulator cock is now placed high, at the outlet of the saturator box. If one uses the regulator near where the vapor tube enters the burner that is a somewhat different affair. My experience was that if the pressure in the saturator box is increased and then regulated by this lower valve, when the vapor passed into the burner, it had a higher velocity, and that the effect of this velocity had not entirely died away before the issuance of the vapor through the perforations constituting the burner tip; so that there was apparently a stiffening of the sides of the flame; the blue part of the flame went higher with the added pressure and by thus decreasing the luminous area, the candle-power was lessened.

The saturator box was certainly intended in the beginning, as

Dr. Harcourt has said, to be used with its inlet cock open, thus maintaining a constant pressure head. I have always gone on the assumption that with a constant pressure head, with uniform fuel fed through a constant orifice, there would be a constant consumption, and therefore a constant flame, leading to a constant candle-power.

The third point which is of great interest and which is very important indeed is the quickness with which they claim pentane as now furnished to the market seems to change its density. Mr. Crittenden has said that after one-tenth of it has been used the residue is already well beyond the limits set for the density of the pentane. It hardly seems possible that this could have been true at the time Dr. Harcourt invented his lamp and made the specification for its use. I am wondering whether it is not now possible to meet the tests provided in the specifications and yet not supply the exact article that was intended in the original specifications. If I remember aright, the specification of light American petroleum such as is known as gasoline from which to refine the pentane, referred originally to Pennsylvania oil with a paraffin base. This is not so readily supplied now as formerly, and it may be due to this lack of a paraffin base that the Bureau has found such a rapid change in the pentane density. I do not claim any knowledge in this direction (but the matter is of such importance to the reputation of the pentane lamp as a standard of reference, that the subject should be investigated further, and access be had to original records in England to find where this discrepancy has crept in).

Mr. C. W. Jordan: I would like to inquire in regards to the relative accuracy of carbon dioxid determinations in air with a Zeiss refractometer and by chemical methods. It occurred to me that the refractometer shows its greatest accuracy when only two constituents of a gaseous mixture are variable. By Pettersson's chemical method, carbon dioxid in air can be determined accurately to within 0.002 per cent.

Have the authors of this paper made any extensive investigations of pentane from a chemical standpoint? While the fuel consumed in the lamp is designated by the formula C_5H_{12} it is admittedly not pure pentane. In fact the portions distill off

between 25° C. and 40° C. which precludes a definite compound. Prepared from the rather vaguely defined American petroleum, it is said to consist chiefly of pentane with small quantities of lower and higher homologues whose presence does not affect, seriously, the candle-power of the lamp. Pentane is the fifth of the paraffin series of hydrocarbons, the first four of which, methane, ethane, propane and butane being gaseous at ordinary temperatures. Methane burns with a non-luminous flame and the candle-power of the succeeding compounds increase progressively, due to the increase in the percentage of free carbon dissociated. Pentane is known to exist in three modifications, each having different boiling points, and the separation of admixtures of propane, butane and the higher homologue, hexane, is very difficult.

For lack of evidence to the contrary, I am inclined to believe that serious variations in candle-power may occur in different lots of pentane having the proper specific gravity and giving negative tests for the hydrocarbons of the benzene series. I think that flame standards should consume a definite, chemically pure fuel and in the case of the Harcourt pentane lamp, synthetically produced pentane would be the ideal fuel.

On the fourth page of this paper a statement is made that pentane lamps, manufactured by the same maker and supposedly of the same type, sometimes show variations in candle-power of as great as 4 per cent. This variation is believed to be due to mechanical differences in the lamps. While it is exceedingly important to standardize lamps under the existing conditions, I think that the line of future investigation should be that of drawing up standard specifications to eliminate these differences.

Mr. E. C. Crittenden (in reply): Mr. Bond's complimentary remarks regarding the work done on pentane lamps at the Bureau of Standards are very gratifying. It is a pleasure also to acknowledge our indebtedness to Mr. Bond for valuable suggestions which he has given us at various times during the progress of this work. The position which the pentane lamp now holds in this country is due in no small degree to the pioneer work which he did in introducing it, and his thorough personal knowledge of the lamp gives much weight to his suggestions.

It has been stated that the relative temperatures of various parts of the air circulating system of the lamp are probably the cause of most of the changes in candle-power which occur when the lamp is operated under different conditions. The case in which a change of candle-power was brought about by substituting a solid rod for the usual hollow one at the base of the lamp is an interesting example, which would be hard to explain in any other way. Since the temperature may be appreciably affected by apparently unimportant changes in the conditions of operation, it is evident that if the lamp is to be enclosed, great care must be taken to make sure that the enclosure does not affect the candle-power. As is stated in the paper, it is better not to use any screening except that necessary to shut out stray light. The additional screens described were used because of unfavorable conditions in the laboratory, which would otherwise have prevented accurate measurements at times when drafts were bad; the particular screen described was found by comparative measurements to give no perceptible effect on the candle-power.

With regard to the change in density of the pentane and the possibility that the pentane commercially supplied at present is not the same as when the standard was adopted by the Gas Referees, because the source of supply is different, I would say that if the material is prepared according to the Referees' directions the products obtained from various kinds of crude oil ought not to differ materially. Chemists who have studied various oils say that the differences between them are largely in the heavier constituents; so far as the very light fractions are concerned, Western oils are not essentially different from Pennsylvania oil. In the paraffin series the next substance above pentane is hexane, and that form of it which appears in petroleum has a boiling point of about 60° C. The four distillations specified below that temperature ought to remove the hexane quite completely. The final distillation is carried over the rather wide range from 25° to 40° because the pentane itself exists in two forms having boiling points about 28° and 36° C. Incidentally, the densities of the two forms are 0.625 and 0.631, and it is not clear why the referees set the narrow limits of 0.6235 to 0.626 in the specifications.

There is little danger of errors arising from failure to remove

the other members of the paraffin series, but amylene (C_5H_{10}), of the olefine series, cannot be separated from the pentane by distillation alone, because it has several forms whose boiling points come between 25° and 40° C. The sulphuric acid treatment prescribed should, however, remove it; the permanganate test is supposed to show whether this has been properly done.

It is by no means certain that the pentane on the market is prepared in accordance with the Referees' directions. To make up a mixture which shall have the required density is not difficult, and consequently it is desirable that the chemical test be made.

By repeated distillation, or by synthesis, it is possible to obtain practically pure pentane, but the cost would prohibit its use in testing. If it were a matter of setting up a primary standard the pure fuel might be prepared. There are, however, other difficulties to be met before the lamp can be seriously considered as a primary standard; some time it may be so perfectly understood that we shall be willing to base the unit upon it, but personally I would say that our hopes of attaining that end are not high.

T. J. Little, Jr.: I notice on the twenty-third page it is stated that "The chart is plotted for the pentane lamp, but so far as we know it may be applied to other forms without introducing serious errors." I suppose that is meant for the naked flames, as for instance, flat flame gas burners, but in the accurate determination for candle-power of incandescent mantle burners such as those for use on either gas or gasoline, would you also recommend certain correcting factors?

EXPERIMENTS IN THE ILLUMINATION OF A SUNDAY-SCHOOL ROOM WITH GAS.*

BY EDWIN F. KINGSBURY.

Synopsis: The author describes the lighting by gas of a typical Sunday-school room, composed of a large central floor with a high glass paneled ceiling and alcoves at the ends. Four 4-burner "arcs" having a magnet-valve pilot system of control from the main floor were placed above the ceiling to light the central area. The alcoves were lighted from the side walls by placing a large semi-circular translucent screen in front of each of the eleven upright burners. The object of these screens was to transmit part of the light directly and to reflect a portion back on to the wall. The whole forms a light source of large area and low intrinsic brilliancy.

When planning the lighting of a church, the auditorium is usually carefully studied from every angle to secure ample, uniform illumination and to bring out the best artistic effect. By the time the Sunday-school room is reached ideas of economy become strong and almost any style of illumination is made to do, though this room may actually be used more frequently and for more varied purposes than the auditorium. While, from the nature of the two rooms, it may not be desirable to aim for the same effect in the Sunday-school room as in the church proper, still the lighting of the former should be carefully studied to include the best principles of a good practical installation.

The purpose of this paper is to describe some experiments in the illumination of the Sunday-school room of the Summit Presbyterian Church, of Germantown, Philadelphia.

This room is typical of many used for Sunday-school purposes, being composed of a large, open central portion with alcoves at two sides which can be closed and utilized for classes.

The lighting requirements for such a place demand that the sides shall be treated more as distinctive rooms and that two separate plans of lighting be adopted. The most usual solution

* A paper read at the seventh annual convention of the Illuminating Engineering Society, Pittsburgh, Pa., September 22-26, 1913.

provides one or more chandeliers over the main floor and a smaller one in the center of each alcove. In the present case there was a stained glass ceiling over the center which could be used advantageously and in each alcove there were two wall outlets that it was desirable to use.

There were several reasons for placing the light sources above the ceiling in the central portion. First, it removed the light from the field of vision and, secondly, it utilized the beauty of the stained glass, which any lamps hanging below would tend to obscure. Then, also, the attic was easy of access for maintenance purposes.

The problem of lighting the sides was a more difficult one to solve, as, utilizing the present outlets, brought the lights too low, especially as an audience sits where the light from one row of lamps would be square in the eyes. Even well frosted globes were objectionable, as the walls were dark and the contrast strong.

In accordance with what has been said the work may conveniently be divided into two portions—the first dealing with the permanent lighting of the central portion of the room through the stained glass ceiling and the second with a temporary installation along the front and rear to illuminate the alcoves.

The plan of the room, with essential dimensions, is shown in Fig. 1. The room is 60 ft. (18.29 m.) long by 35 ft. (10.67 m.) wide and 35 ft. (10.67 m.) high. Twelve feet (3.66 m.) from the front and back walls open archways rise, the walls in front at the top curving inwardly to meet a glass paneled ceiling 28 ft. (8.53 m.) long by 42 ft. (12.80 m.) wide, each panel being 3 ft. by 3 ft. (0.91 m. x 0.91 m.). Heavy blinds slide between the arch posts at the rear to form three separate rooms. The wall north of the main floor, composed of three heavy Venetian blinds which can be raised to include the low-ceiling room beyond it as a part of the school room, rises to only one-third of the full height of the room, the space above being entirely open. These three blinds, however, were closed throughout the test. At the south are large double sliding doors in the center, the body of the wall being plain and curving inwardly at the top to meet the ceiling, as in the front and rear. Wooden wainscoating 5 ft. (1.52 m.) high ex-

tends around the room, the north side excepted. All wood work is dark oak in color and the walls dark green.

The room is lighted in the daytime by three large stained glass windows at the rear. The three windows in front are now of no use, being covered by a later built portion of the church.

The body of the room was originally lighted by 12 small inverted incandescent gas burners at each end, distributed uniformly along each horizontal beam 15 ft. (4.57 m.) high at the base of the arches and supplied with pilots and pendant chains for lighting.

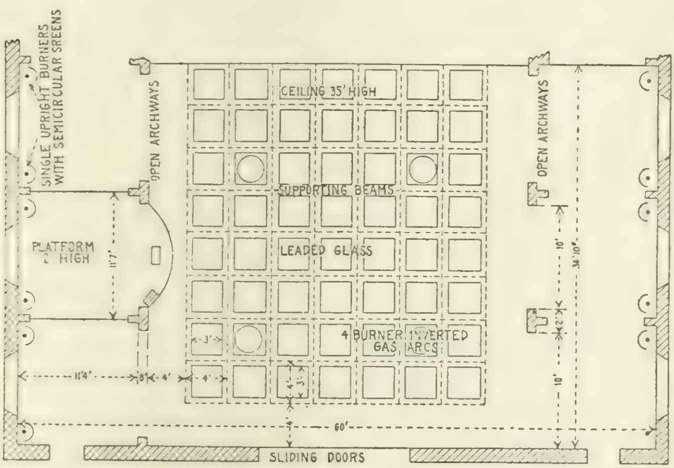


Fig 1.—Plan of room.

The illumination of the alcoves was provided by three small inverted units and several open flame burners. This installation was unsatisfactory, for at least two reasons. First, the mechanical operation of reaching up with a hook to catch 24 rings was both monotonous and time-consuming, especially if the room was rather dark at the start, or if many rings were accidentally set to swinging before being caught. Secondly, the glare from the row at one end in the eyes of a person sitting at the other end was annoying.

These two rows of units lighting the body of the room were,

therefore, removed and the glass paneled ceiling utilized by placing a four-burner inverted incandescent gas arc lamp above each of four panels, as indicated by the circles in Fig. 1. The magnet-valve pilot system of ignition is used. Two push buttons are located on the main floor near the southeast door; each one lights a pair of lamps. Each lamp is equipped with a polished aluminum conical focusing reflector 11 in. (27.94 cm.) diameter at the top, 26 in. (66 cm.) at the bottom and 16 in. (40.64 cm.) high. The mantles are 30 in. (76.2 cm.) from the glass ceiling and the bottom of the reflector 16 in. (40.64 cm.). Opal globes were decided upon as the most suitable. Clear globes gave a bright spot in the center with bright concentric rings. The spots were not visible without the effort to look up at a high angle at the lights, but the illumination on the floor below any lamp was nearly double that half-way between. Opal globes, however, obviated this difficulty, as shown in Figs. 4 and 5. This system has been in use a year and a half and has given satisfaction.

The desultory lighting in the rear of the arches was untouched until recently, when the experiment described below was tried. This consisted of placing upright incandescent gas burners on the six outlets in the front and on five of the six in the rear. Ten inches (25.4 cm.) in front of each lamp was a semi-circular translucent paper screen, highly glazed on the inner side and matt on the outer. A plain creamy-white bathroom wall paper answered the temporary purpose very well. The object of this was to have the glazed surface reflect part of the light to the wall. Then the light reflected from the wall, with that fraction transmitted by the screen, is supposed to form a continuous light source of large area and low intrinsic brilliancy. The position of the curve is imitative of daylight window illumination and should partake of the naturalness of the latter. If the wall is ornamental the screens may well be. In the present case both were left plain. The screen, ten inches (25.4 cm.) high with a radius of ten inches (25.4 cm.) and having the light at the center, shields the source from practically every position a person would be likely to assume. The exception is that when one sits sideways and almost directly beneath a lamp the bare mantle can be seen by

looking upward. This can easily be remedied by making the screen a little wider or lowering the present one somewhat.

In order to prevent too much light being thrown back against the wall and to direct more obliquely to the floor, as sunlight would be, a small rectangular piece of bright tin was placed (experimentally) directly in the rear of each mantle, allowing it to slant forward a trifle. By selecting the proper width and angle for such a reflector any desired effect in this connection could be obtained.

Owing to the high absorption of the wall and woodwork, the employment of a more efficient diffusive surface back of each unit was imperative to secure sufficient illumination. For this purpose a semi-matt white paper 36 in. by 36 in. (0.913 x 0.913 m.) was pasted on the wall.

Fig. 2 shows the front of the room and Fig. 3 the rear under this artificial illumination. In the former can be seen the light reflected from the floor, which appears as a bright band running parallel with the wall. It will be noted at the top of the picture, above the horizontal beam, that there is considerable light thrown obliquely upwards and a design painted on the under side of the arches was brought out conspicuously clear. Unfortunately the wall near the ceiling could not be changed, but if it were white or a light cream it would help out in a line where most needed—the transition from the side to the main overhead illumination.

The uniformity of the screens and background is shown in both pictures where they cannot be distinguished, except at an oblique angle, as in Fig. 3. This system seems to solve successfully the illumination of the alcoves.

In Fig. 6 is shown a candle-power distribution curve of one of the wall units, taken through the plane bisecting the central angle of 180° subtended by the screen. Each arm of the curve has its own particular function. The two back loops go to the wall to be reflected, one to the floor and the other at an oblique angle toward the ceiling, while a considerable part of both will be diffused into the space in front of the unit. The upper front one goes to the ceiling and the lower front one to the floor. It is desirable to have the curve directly in the rear of

the screen swing in more, as the light thrown straight back is more or less useless. This can be partially accomplished by making the tin reflector larger, or by having the semi-circular screen not as a section cut from a cylinder, but as a section of an hourglass. Even then any diffused light would keep the wall quite bright.

Illumination measurements were taken with all the room fully lighted, and with the center lamps and the lamps at one end lighted separately, the object being to show the effect of the two distinct systems on each other. All readings were taken in a 30 in. (76.2 cm.) plane, with the exception of the readings on the platform, which were made on a plane 2 ft. (60.96 cm.) higher than those on the floor.

Fig. 4 shows the first case when all the lamps are at maximum brilliancy. This seems to give the best effect and with the light properly spread no fatigue or annoyance should be experienced by an audience facing them for several hours. However, the alcove lighting is very elastic, and if the maximum light desired at one time is considered excessive at another time, the lamps can easily be turned down, as they are upright burners and will work equally well at any intensity.

An analysis of the results shows a high candle-power close to the lamps, with a rapid falling off to a minimum directly beneath the arches. Then comes a gradual rise to a maximum on the main floor.

Fig. 5 shows the center and one end lighted separately. As will be noted the end wall illumination has an appreciable effect on the main floor, the result being to enlarge the contours. It would be more desirable if the ends sent more light beneath the arches, and this could easily be secured by making the entire wall much lighter.

The average foot-candles on the 30 in. (76.2 cm.) plane in the center is 1.08. While this may seem low, it has proven to be ample for all purposes and there seems to be a peculiar advantage in reading responses or singing where the book is held fairly horizontal. The vertically directed light here from a height gives one a feeling the same as that experienced in cathedrals and is hence

Fig. 2.—Front of room lighted.

Fig. 3.—Rear of room lighted.

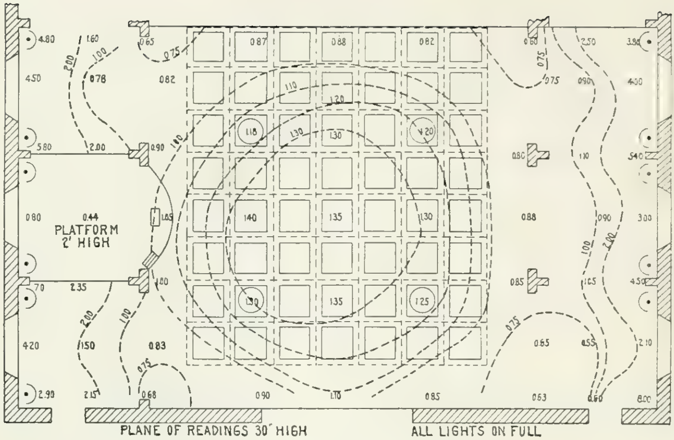


Fig. 4.—Illumination readings.

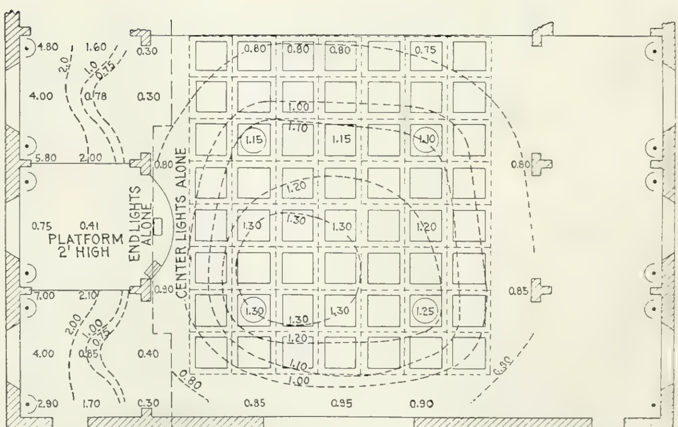


Fig. 5.—Illumination readings.

appropriate. Experience has shown the body of the room is sufficiently well lighted by the four arc lamps, but they have little influence back of the arches.

There are spots under the archways where the illumination is a trifle too low to allow of continued reading, but these would be corrected by lighter side walls in a finished installation.

This installation is described with the purpose of showing that in rooms so cut up and apparently hard to illuminate well, the very peculiarities may be used to provide something at once unusual and practical. Certainly, the illuminating engineer should not feel that any situation is so commonplace and unimportant

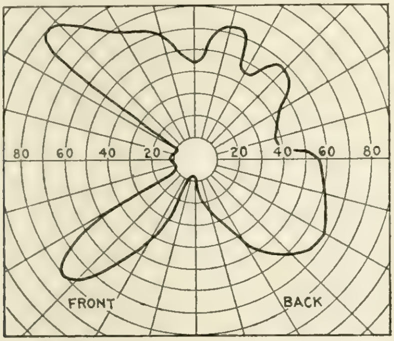


Fig. 6.—Candle-power distribution through vertical plane of an alcove unit.

that any casual style is good enough, but he should be alive to every opportunity to make the uncommon out of the common. This means that while there are certain fundamental rules always to be observed, they make only a beginning, and the remainder of his task depends on his originality. This is not assuming, of course, that expense is to be overlooked. In the case described above a relatively costly installation was a poor one. It means that thought and study must be given to each individual case.

The thanks of the author are due to Mr. Charles O. Bond, Dr. Herbert E. Ives and Mr. C. W. Jordan for assistance in preparing this paper.

DISCUSSION.

Mr. J. D. Israel: I feel privileged to discuss the question of church lighting from a commercial standpoint. The psychological effect of lighting, discussed by Dr. Lewis* yesterday, I think should be considered when one studies church lighting problems from a purely commercial standpoint.

I wish to say for your information that the Philadelphia Electric Company approaches this problem purely on a commercial basis, the same as they go after business in any other class of lighting. We address letters to the trustees and pastors of the various churches; we circularize and give illustrations of such installations as we already have connected to our circuits. Then we follow with personal appeals; our men appear before the trustees. We ask the pastor and trustees to consider the matter as a commercial problem, as an aesthetic problem and as a religious problem. We accomplish good results without detracting at all from the sacredness of the work.

Mr. E. F. Kingsbury: One use of the alcove lighting not mentioned in the paper is in the illumination of small rooms, especially in residences, where there are wall outlets that one dislikes to use on account of the difficulty in avoiding objectionable glare from them. With a little care the light thrown downward can be utilized for reading on a table near the wall and the light thrown upward will supply the general illumination. The success of such an installation depends on keeping the brilliancy of the screen and reflecting walls low. This is well secured on the screen and an artistic end realized if it is made ornamental. In this way an almost useless outlet might be turned into a thing of beauty.

* "The Psychic Values of Light, Shade, Form and Color," Trans. I. E. S., p. 357 (October, 1913).

CHARACTERISTICS OF ENCLOSING GLASSWARE.*

BY VAN RENSSELAER LANSINGH.

Synopsis: In this paper, enclosing glassware is divided into two classes: one, purely transmitting and diffusing, such as ground, opal and leaded glass; the other, prismatic glass, which employs the principle of specular reflection. Photometric curves and data are given to show (1) that with glassware of the first class, little except good diffusion and low absorption may be expected, the re-distribution of light being negligible; (2) with prismatic glass, the distribution may be varied in accordance with the wishes of the engineer. The absorption in both given classes is about the same.

The two most pronounced tendencies of the day in interior illumination, excluding the industrial field, are, first, the use of indirect and semi-indirect lighting, and second, enclosing glassware. By the latter is meant the use of large diffusing glassware, completely surrounding the lamp. A great deal has been written in the technical press and elsewhere on the first class, but little has appeared regarding the second. The present paper, therefore, aims to state briefly some of the chief characteristics of this class of lighting units. So far the writer has made a study only with tungsten-filament lamps, but with the possible exception of some changes in color characteristics, it is believed the same results would be obtained with gas mantle burners. This cannot be said of arc lamps, however, when the position of the arc travels, and no attempt is made here to cover this phase of the subject.

The chief characteristics of enclosing glassware are: (1) distribution, (2) absorption, (3) appearance, (4) effect on the eye, (5) effect on the lamp, and (6) color.

The question of appearance, color, and effect on the eye are not taken up here, as these subjects have been covered by numerous writers in the *Transactions* and elsewhere. The effect on the lamp need not be given much consideration as a number of tests have shown that the rise in temperature, due to enclosing the lamp, is not sufficient to affect its life.

The tests reported in this paper were made at three different

* A paper read at the seventh annual convention of the Illuminating Engineering Society, Pittsburgh, Pa., September 22-26, 1913.

laboratories, whose methods and results have been carefully checked against each other; so that the curves given are all comparable. Inasmuch as comparative rather than absolute values are desired, the curves are given without the actual candle-power. All curves, however, are plotted on the basis of 1,000 lumens for the bare lamp, *i. e.*, the candle-power actually found at every reading in the tests is multiplied by the ratio of 1,000 to the actual lumens of the lamp. Thus, in the case of a 100-watt lamp giving 908 lumens, the candle-power readings would be multiplied by $\frac{1,000}{908} = 1.1$. By thus reducing all the curves to the basis of a 1,000 lumen lamp, the curves can be compared without reference to the size of lamps used. For example, it will be noted that the bare lamp curve is the same in every case, irrespective of the size of lamp tested. In every case, the figures given are based on lamp flux rather than emitted flux, as the engineer is really concerned with the actual flux of a lamp which is available for any given purpose, rather than the relative emitted flux in different zones.

There are many different kinds of enclosing glassware on the market at the present time, and typical examples from the different classes were selected for the purpose of the above mentioned tests. The kinds of glassware selected were as follows:

Class I—Pressed opal ball in two pieces.
Class II—Blown opal ball.
Class III—Blown opal acorn.
Class IV—Cased opal ball.
Class V—Leaded opal ball.
Class VI—Ground glass ball.
Class VII—Prismatic deep reflector-bowls.
Class VIII—Prismatic shallow reflector-bowls.
Class IX—Prismatic reflector-balls.

The actual trade names, designations, etc., of the glassware tested, and full data on each test, are given in an appendix to this paper, for those who wish this information. The accompanying illustrations will serve to identify the general appearance, contour, etc., of each unit.

Fig. I shows a two-piece pressed opal ball of comparatively light density, listed above as Class I. Fig. 2 shows the curve of the bare lamp and a 10-inch (25.4 cm.) ball tested with a 100-watt tungsten filament lamp. Fig. 3 shows the distribution from a 14-inch (35.56 cm.) ball with a 100-watt tungsten filament lamp, and Fig. 4 the same with a 250-watt lamp.

It will be noted from a study of Figs. 2, 3 and 4 that a change in the size of lamp or of the size of ball has but little effect in the resulting distribution curves. It will be further noted that the curves all tend toward a circular distribution, denoting good diffusion, but, at the same time, very little redirection of light in useful zones.

Fig. 5 is a picture of a blown one-piece opal ball (Class II), the density being the same, but the thickness being less than in the pressed ball just considered. Blown opal balls of this density and thickness are regularly furnished with the outside sand-blasted or roughened to increase diffusion. Fig. 6 shows the photometric curve of the 12-inch (30.48 cm.) size tested with a 100-watt lamp. It will be noted that the curve is less modified from the bare lamp curve than in the former case showing that the diffusion is not as good.

This is further emphasized by Fig. 7, the right-hand curve being that of the pressed ball and the left-hand one the blown ball. The difference, while noticeable, is not striking. The use of such balls instead of the pressed type, would mean that a greater flux would strike the side walls and less fall upon the ceiling. An appreciably greater flux is also shown in the lower hemisphere. This type of ball is used largely for street lighting purposes and it will be seen that it has a low absorption, namely, about 14 per cent. as compared with an absorption of about 24 per cent. in the case of the pressed type. A comparison of the flux in the different zones as given under the curves shows an increase in the flux from zero to 60° of approximately 22 per cent., and from zero to 90° of 19 per cent. It would seem, therefore, that in most cases, except perhaps from the standpoint of appearance, the blown ball, being much thinner, is preferable for use when there is no objection to a slight image of the filament through the glass.

Fig. 8 shows a blown opal acorn shape (Class III) enclosing unit made of the same glass as the others so far considered, and roughed outside. From its distribution curve, Fig. 9, it will be noted that due to its shape, there is a slight reflecting power which throws more flux in the lower hemisphere. The absorption is somewhat greater than the blown ball, but less than the pressed type, as might be expected. Compared with the blown ball, the acorn gives about the same flux below the horizontal but 10 per cent. more in the 0-60° zone.

Fig. 10 is a cased one-piece opal ball (Class IV) and Fig. 11 the curve of the 12-inch (30.48 cm.) size tested with a 150-watt lamp. Comparison should be made between these and the blown opal ball, a curve of which is shown in Fig. 6. It will be noted that the flux below the horizontal is practically the same but that there is less above the horizontal, resulting in an increase in absorption of about 5 per cent. The diffusion, however, with the cased ball is much better than in the blown opal.

Fig. 12 is a leaded opal ball (Class V), the curve of which, with a 150-watt lamp, is shown in Fig. 13. It will be noted that the absorption is practically the same as that of the 14-inch (35.56 cm.) pressed ball (Fig. 3 and 4). The distribution curve is somewhat different, however, there being slightly more light on the horizontal and less light directly above and below. The results of this test are more or less surprising inasmuch as there is a general idea that most diffusing leaded glass absorbs a large percentage of light. It would seem that this particular type of leaded glass has no greater absorption than the ordinary light density pressed opal ball.

Fig. 14 is the curve of a 12-inch (30.48 cm.) ground glass ball (Class VI) with 100-watt lamp. But little alteration in the curve of the bare lamp is made, although some diffusion is obtained. The diffusion, however, is quite different from that obtained with the opal ball, Fig. 6. A comparison of the two curves shows a somewhat lower absorption in the case of the ground glass ball than with the opal blown ball, but a somewhat lower efficiency in the zero to 60° zone and more light at angles near the horizontal.

Fig. 1.—Two-piece pressed opal ball (Class I).

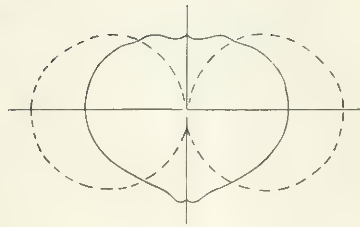


Fig. 2.—Photometric curve of 10-inch two-piece pressed opal ball tested with 100-watt lamp.

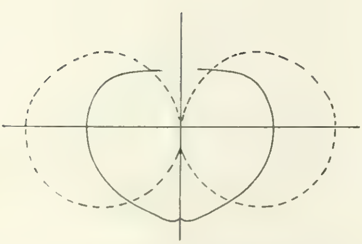


Fig. 3.—Photometric curve of 14-inch two-piece pressed opal ball tested with 100-watt lamp.

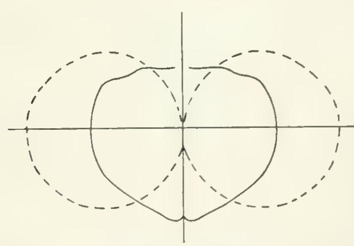


Fig. 4.—Photometric curve of 14-inch two-piece pressed opal ball tested with 250-watt lamp.

ZONAL FLUX WITH 1,000 LUMEN LAMP.

Zone	0–60	0–90	90–180	0–180
Lamp alone	203	512	488	1,000
Fig. 2	182	379	385	764
Fig. 3	190	384	335	719
Fig. 4	182	374	346	720

Fig. 5.—One-piece blown opal ball (Class II).

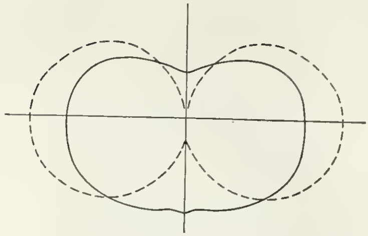


Fig. 6.—Curve of 12-inch one-piece blown opal ball tested with 100-watt lamp.

Fig. 8.—Blown opal acorn (Class III).

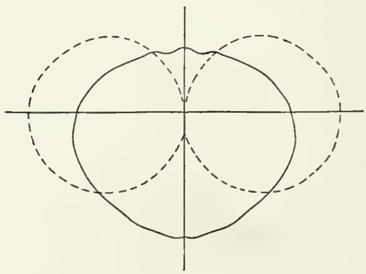


Fig. 9.—Curve of 12-inch blown opal acorn tested with 150-watt lamp.

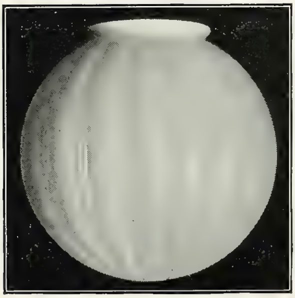


Fig. 10.—Cased opal ball (Class IV).

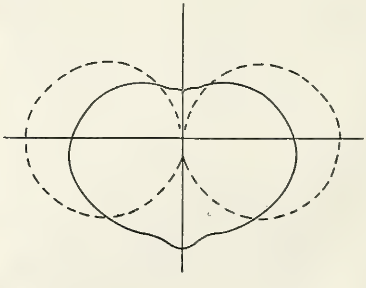


Fig. 11.—Curve of 12-inch cased opal ball tested with 150-watt lamp.

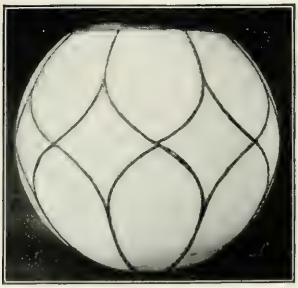


Fig. 12.—Leaded opal ball (Class V).

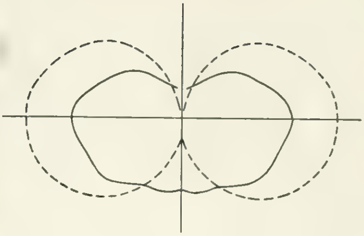


Fig. 13.—Curve of 12-inch leaded opal ball tested with 150-watt lamp.

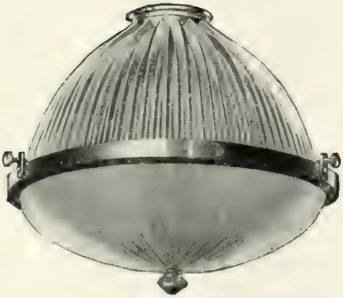


Fig. 15.—Prismatic deep reflector-bowl (Class VII).

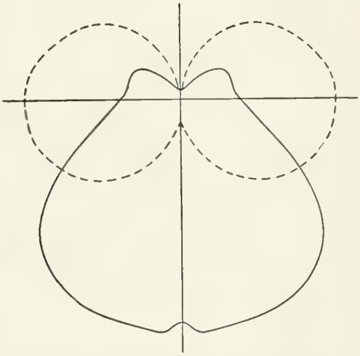


Fig. 16.—Curve of 14-inch prismatic deep reflector-bowl tested with 250-watt lamp.

ZONAL FLUX WITH 1,000 LUMEN LAMP.

Zone	0–60	0–90	90–180	0–180
Lamp alone	203	512	488	1,000
Fig. 6	223	469	395	864
Fig. 9	243	476	347	822
Fig. 11	222	456	359	815
Fig. 13	181	396	321	717
Fig. 14	206	484	419	903
Fig. 16	412	589	180	769

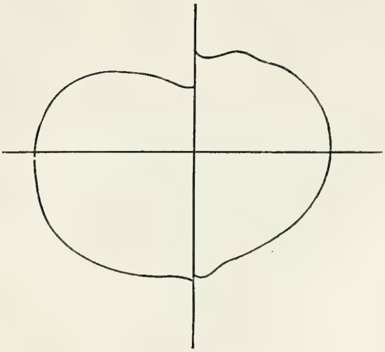


Fig. 7.—Comparison curves of Class II and Class I, Figures 6 and 2.

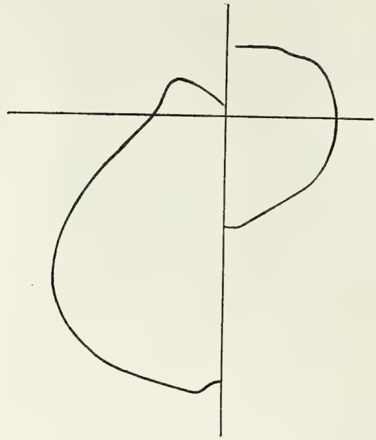


Fig. 17.—Comparison curves of Class VII and Class I, Figures 16 and 3.

ZONAL FLUX WITH 1,000 LUMEN LAMP.

Zone		0–60	0–90	90–180	0–180
Fig. 7	Class 1, Fig. 2	182	379	385	764
	Class 2, Fig. 6	223	469	395	864
Fig. 17	Class 1, Fig. 3	190	384	335	719
	Class 7, Fig. 16	412	589	180	769

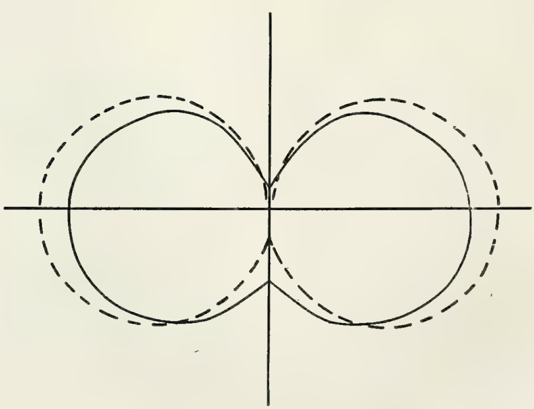


Fig 14.—Curve of 12-inch ground glass ball (Class VI) tested with 100-watt lamp.

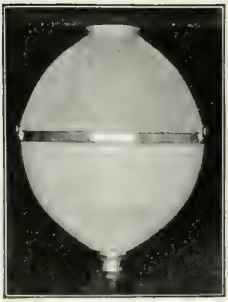


Fig. 18.—Prismatic deep reflector-bowl with special deep bowl.

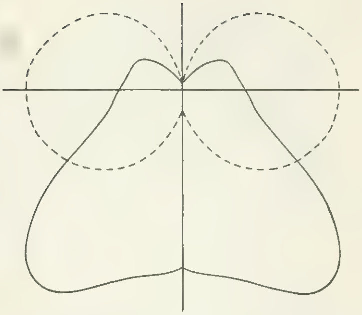


Fig. 19.—Curve of 14-inch prismatic deep reflector-bowl with special deep bowl tested with 250-watt lamp.

Fig. 20.—Prismatic shallow reflector-bowl (Class VIII).

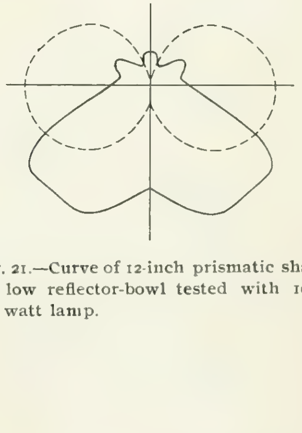


Fig. 21.—Curve of 12-inch prismatic shallow reflector-bowl tested with 100-watt lamp.

ZONAL FLUX WITH 1,000 LUMEN LAMP.

Zone	0–60	0–90	90–180	0–180
Lamp alone	203	512	488	1,000
Fig. 19	420	583	185	768
Fig. 21	362	554	169	723

Fig. 22.—Prismatic reflector-ball (Class IX).

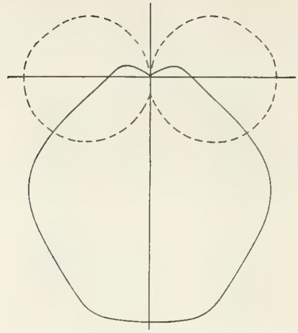


Fig. 23.—Curve of 12-inch prismatic reflector-ball tested with 150-watt lamp.

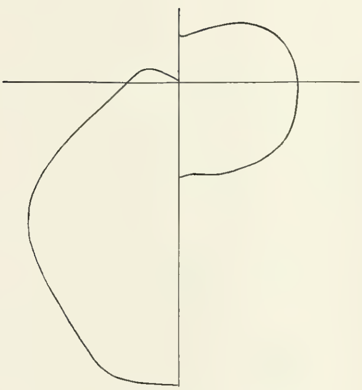


Fig. 24.—Comparison curves of Class IX and Class II, Figures 23 and 6.

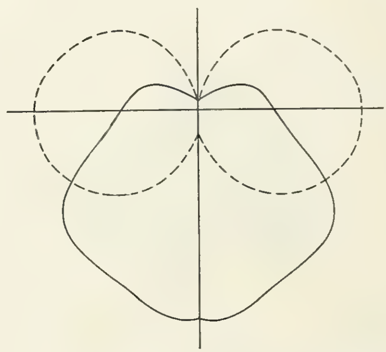


Fig. 25.—Curve of 12-inch prismatic reflector-ball, reflector satin finished inside, tested with 150-watt lamp.

ZONAL FLUX WITH 1,000 LUMEN LAMP.

Zone	0–60	0–90	90–180	0–180
Lamp alone	203	512	488	1,000
Fig. 23 (Class IX)	455	618	103	721
Fig. 6 (Class II)	223	469	395	864
Fig. 25	356	552	182	735

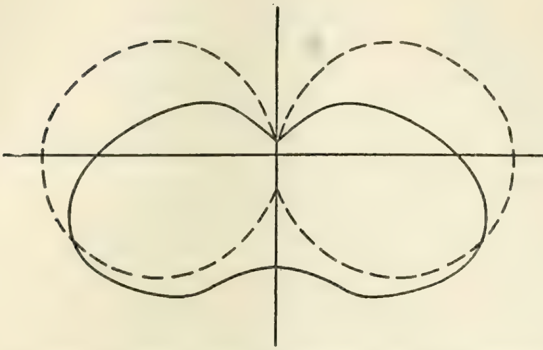


Fig. 26.—Curve of 14-inch prismatic reflector-ball tested with 400-watt lamp with center of filament at center of ball.

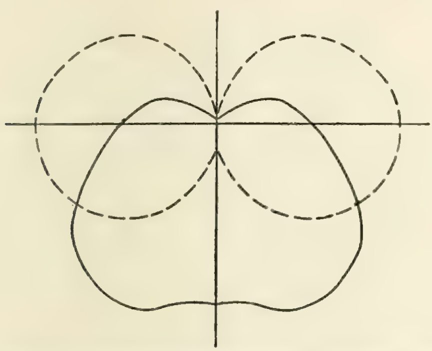


Fig. 27.—Curve of same unit as Fig. 26 but with filament 2 inches higher.

ZONAL FLUX WITH 1,000 LUMEN LAMP.

Zone	0–60	0–90	90–180	0–180
Lamp alone	203	512	488	1,000
Fig. 26	239	522	263	786
Fig. 27	332	551	168	719

With prismatic enclosing units, a most decided change in the resulting distribution may be noted. With opal and ground glass diffusing units, the tendency of all curves is to become circular in shape, with increasing diffusion, but in practically no case is there a large increase in useful flux below the horizontal. In only three cases, Figs. 6, 9, and 11, is the 60° flux greater than that of the bare lamp, being respectively 223 lumens,

243 and 222, as compared with 203 for the lamp alone. The lower hemispherical flux in every case, however, is considerably less than that of the bare lamp, averaging 18 per cent. less, exclusive of the ground glass ball.

The most pronounced redirecting effect is with the blown acorn (Fig. 9) where 24.3 per cent. of the lamp flux is within the 0-60° zone. A comparison of this with Fig. 23 shows the remarkable difference which can be obtained by the use of specularly reflecting media. In the latter case, no less than 45.5 per cent. of the flux is within this zone, an increase of 77 per cent.

Fig. 15 is a prismatic deep reflector-bowl, with a diffusing bottom, a photometric curve of which is shown in Fig. 16. This distribution is an intensive type and by far the greater flux is below the horizontal: 41 per cent. is within the 60° zone, and 59 per cent. is below the horizontal. The total absorption is about 23 per cent.

Fig. 17, a comparison of Figs. 4 and 16, is interesting. The former curve, that of the two-piece pressed opal sphere, shows only 18.2 per cent. of the flux in the 60° zone as against 41.2 per cent. for the prismatic deep reflector-bowl; that is, the latter unit utilizes about two and a quarter times as much flux in this zone. The lower hemispherical flux is 58.9 and 37.4 for the reflector-bowl and opal ball, respectively, with an absorption of 21.3 per cent. and 28 per cent. in each case.

Fig. 18 shows a modification of the unit shown in Fig. 15, the shallow bottom bowl being made much deeper in the form of an acorn. The resulting photometric curve, Fig. 19, is not greatly altered, although the general shape looks more like the extensive type of distribution than the intensive type. The principal difference is the flux between zero and 30°.

Fig. 20 shows a shallow prismatic reflector-bowl unit, the bowl having shallow external redirecting prisms, and Fig. 21 the resulting distribution curve. It will be noted that this gives a broad distribution, much broader than that shown in Fig. 16 and 19, but the zonal and overall efficiency is somewhat lower. Of the total lamp flux, 36 per cent. is within the 60° zone and 55 per cent. below the horizontal while the absorption is about 28 per cent.

Fig. 22 shows a prismatic reflector-ball, the reflector being separate from the blown globe and resting on a shoulder made for that purpose. The lower half of the ball is satin finished, but the part under the reflector is clear. Fig. 23 shows the distribution curve obtained from this unit with the lamp in the standard position. It shows a remarkable control of light, 45.5 per cent. of the lamp flux being within the zero to 60° zone and 61.8 per cent. below the horizontal; while the total absorption is about 28 per cent. A comparison (Fig. 24) of this unit with the blown opal ball (Class II, curve shown in Fig. 6) is even more striking than the comparison in Fig. 17. The flux in the zero to 60° zone is 45.5 per cent. of total lamp flux in the case of the reflector-ball and only 22.3 per cent. with the opal ball, the corresponding figure for the lower hemisphere being 61.8 per cent. and 46.9 per cent. while the absolute absorption is 27.9 per cent. and 13.6 per cent, respectively. The relatively low upper hemispherical flux shown in this reflector-ball is quite remarkable and strikingly illustrates the light control which is possible in prismatic combinations, even with a secondary globe between the light source and the active reflector as is the case in the larger sizes of this type of unit.

Fig. 25 shows the distribution from the same unit but with the reflector satin finished on the inside. It will be noted at once that there is a considerable decrease in the flux below the horizontal and an increase in that above, 35.6 per cent. being within the zero to 60° zone and 55.2 per cent. below the horizontal. While this is a considerable decrease from that obtained with the clear reflector, it should be compared with the best of the opal types, that is to say, the acorn shape where only 24.3 per cent. of the light, as compared with 35.6 per cent. in this case, is below 60°. Where the softer appearance of ground glass is desired, a unit of this type combines efficiency and such an appearance.

Considerable variation in distribution may be obtained in the case of the reflector-balls shown in Fig. 22 as will be seen in Figs. 26 and 27 where a 14-inch (35.56 cm.) ball of this type with a 400-watt lamp was used in both cases but with the center of the filament in the first case at the center of the ball and in the

second case, 2 inches (5.08 cm.) above. The difference in distribution is quite remarkable and shows that by proper placement of the lamp, wide variations in distribution can be obtained.

SUMMARY.

From a distribution standpoint, enclosing glassware can be divided into two distinct classes, one purely transmitting and diffusing, such as ground glass, opal glass, etc., and the other, prismatic glass, where the principle of specular reflection is employed. With glassware of the first type, little except good diffusion and low absorption can be expected, the redistribution of light being negligible. In the case, however, of prismatic glass, it is possible to vary the distribution in accordance with the wishes of the engineer. It is to be noted further that the absorption of light in both classes is about the same.

The writer regrets that it has been impossible for him to have conducted depreciation tests on the different units, as this phase of the subject, namely the loss of light and change in distribution due to dust, should not be overlooked.

APPENDIX.
Data on Tests.

Fig. No.	Test on.	Cat. No.	Dia. inches	Mfr.	Test by*	Test No.	Lamp watts	Lamp Position
2	Pressed "Alba" ball	3482	10	Macbeth-Evans Glass Co.	B	3342	100	Centered
3	"	3485	14	"	A	5242	100	"
4	"	"	"	"	A	7495	250	"
6	Blown "Alba" ball	2690	12	"	B	4291	100	"
9	Blown "Alba" acorn	3658	12	"	B	4238	150	"
11	"Melilite" ball	5124	12	Gillender & Sons	B	4213	150	"
13	Leaded opal ball	111180	15	"Monolux" General Electric Co.	C	1109	400	"
14	Ground glass ball	—	12	—	A	4382	100	"
16	"Holophane-Realite"	8342	14	Holophane Works of G. E. Co.	A	6627	250	Form A
19	Deep "Holophane-Realite"	7214	14	"	A	8398	250	"
21	Holophane reflector-bowl	7912	12	"	A	6241	100	"
23	Holophane reflector ball	9612	12	"	A	9035	150	Center of filament 2⅝″ above center of ball
25	"	"	"	"	A	8955	"	"
26	"	9814	14	"	C	1668	400	Centered
27	"	"	"	"	C	1668	"	Center of filament 2″ above center of ball

*A—Eng. Dept., Holophane Works of General Electric Co. B—Eng. Dept., National Lamp Works of G. E. Co. C—Illuminating Engineering Laboratory of General Electric Co., Schenectady.

DISCUSSION.

Mr. H. S. Dunning: In abstracting his paper Mr. Lansingh brought up the question of the performance of incandescent lamps in enclosed globes. In the laboratory of the company with which I am connected, we have been making recently a series of experiments in which we found it necessary to burn several of the 100-watt size tungsten lamps in a small container. The container was lined with asbestos and there was very little, if any, ventilation. The experiment which we were making depended in no way on the maintenance of the lamps, but as a matter of interest we tested them from time to time and found very little change. I do not believe that under ordinary conditions the life of the tungsten lamp is materially shortened by using glassware which practically encloses the entire lamp.

Mr. S. G. Hibben: This paper, contains some very excellent photometric data on the particular types of enclosing units that are shown here. But I think I am justified in saying that it is hardly a fair proposition to give the distribution curves of totally enclosing units and having selected that particular unit which gives the most light in a downward direction, to then conclude that every time, or under all conditions, this particular type of enclosing unit is the only one that is "efficient" or justified in its use.

The conclusion states that with diffusing glassware, little except good diffusion may be expected, the redistribution of light being negligible. This statement will bear considerable qualification. In the first place the positioning of the lamp in the globe will greatly change the results, and if in these reported tests the lamps had not been placed so as to give in some cases the maximum downward reflection, and in others to give distinctly different distribution, the conclusions could not have had such an apparently strong foundation. Secondly there is a change in distribution with a change in shape, even with diffusing glassware. A conical or parabolic shaped reflector made of white or the so-called opal glass, with a diffusing plate beneath, would in fact give considerable redirection of light. The above statement about negligible re-distribution can correctly apply only to a spherical shaped or a very nearly spherical shaped

diffusing globe, of the same quality and finish of glass throughout.

The user of a diffusing unit may have in mind the attainment of a re-direction of light, but he also wishes low intrinsic brilliancy of the source, a considerable degree of ornamentation, and possibly a slight color effect. If he wishes downward reflection primarily, he uses, or should use, an open bottom shade. And if the enclosing globe meets all these requirements except the first, it may be used efficiently in the broad sense of the word, and its use is justified.

I wish to add that, inasmuch as it is the policy of the society to exclude from the TRANSACTIONS the special trade names of various products, when such trade names are excluded, the proper general name ought to be supplied in every case. I do not wish to criticise the present paper on this point, but I refer here specifically to the word "opal' in describing glasses that are not opal in any sense of the word. In fact, if the two-piece unit of Fig. 1, were actually made of opal glass, as is stated, then each radius of the photometric curve shown in Fig. 2 would be reduced at least one-third.

In short, "opal" is not the proper term to apply to the majority of the diffusing units that have been discussed here. I would like to suggest in this case to have the proper committee take up this matter of nomenclature.

The words "opal" and "opalescent" have been used rather loosely. "Opal" describes a particular class of glass, as does "crystal," or "alba." There is a sharp distinction between opal and alba glasses. The opal is a very great absorber of light, and in some thickness or another will always show a yellowish-red color of transmitted light. You might use the term "Mazda" in speaking of all metal filament lamps, whatever the metal or the burning efficiency, and this would be no further wrong than to misuse these terms I speak of.

This is a point I wish to bring out very strongly, that the word "opal" be limited to describing those glasses that are really opal, and that it be not applied to all white diffusing glasses.

MR. V. R. LANSINGH: (In reply): Mr. Hibben spoke of the

possibility of having different shapes in diffusing glassware to give different photometric curves. It may be possible to do this.

The paper does not attempt to make any comments whatever as to the use of the glassware which was tested, and consequently I will say nothing with regard to Mr. Hibben's remark on that subject, as it is extraneous to the paper itself.

As regards the use of the word "opal," I should be very glad indeed to have some better word, but at the present time I know of no more definite classification unless we use the trade names themselves.

THE PHOTO-ELECTRIC CELL IN PHOTOMETRY.*

BY F. K. RICHTMYER.

Assistant Professor of Physics, Cornell University.

Synopsis: On account of some special peculiarities, the photo-electric cell presents some interesting possibilities for photometric use. Since the discovery of the so-called photo-electric phenomenon in 1888, the process of manufacture of the cells has been so perfected that cells of sodium, potassium, or rubidium, sensitive to light from the visible spectrum, are readily obtainable on the market. Since the intensity of the current furnished by these cells is strictly proportional to the intensity of illumination on the sensitive metal surface, the cells may be used for intensity measurements over a very great range. For the lower intensities an electrometer must be used; for higher intensities a sensitive galvanometer is permissible. Diagrams of connections, and some suggestions for the several methods of using an electrometer are given. To use photo-electric cells for photometric purposes however, one must be perfectly familiar with their peculiarities. For example, the wave-length sensibility curve lies much farther toward the violet than does the luminosity curve for the human eye. So that if used for ordinary photometry a specially selected set of absorbing screens must be available. But in spite of some difficulties attending its use, the high sensibility and the peculiar action of the cell as a time integrator of light intensity make it particularly desirable for special photometric purposes.

The photometrist and student of illumination—especially when working in the research laboratory—frequently meets conditions which make it desirable to use an apparatus for measurement which eliminates, in part at least, some of those ever-present difficulties incidental to photometry by the human eye. It may be desired to avoid various physiological and psychological effects. Precision greater than that available by eye measurement may be necessary. The illumination may be of too short duration for observation by ordinary means. Of the various devices available for use in such cases none deserves greater attention than the so-called photo-electric cell. In the hands of one who fully understands its use and its limitations, it should prove a most

* A paper read at the seventh annual convention of the Illuminating Engineering Society, Pittsburgh, Pa., September 22-26, 1913.

valuable addition to any laboratory. It is the purpose of this paper to point out, in very brief outline, some of its characteristics, peculiarities, and advantages, and to give several specific examples for its use.

HISTORY.

Those who have not followed the development of the photo-electric cell may be interested in knowing that as far back as 1888, Hertz—to whom perhaps more than any other we owe the wireless telegraph—discovered that under certain conditions a metal plate, connected to the negative terminal of an electric generator, the positive terminal of which was grounded, and illuminated by the ultra-violet light from a spark, would discharge into the air or to a nearby grounded wire a continuous stream or current of negative electricity. In the early '90's this interesting relation between light and electricity was the subject of much investigation. Among other things, it was shown by Elster and Geitel,[1] that the alkali metals, particularly sodium and potassium, were sensitive to light from the visible spectrum, especially to blue and violet. On account of the rapidity with which these metals oxidize when exposed to the air, it was necessary to study them in an atmosphere of some inert gas. For this purpose, Elster and Geitel devised a method, which has since been perfected, of pouring the metals, in molten form, into a small glass bulb containing hydrogen or helium and having the necessary external electrical connections. These are the photo-electric cells which may now be obtained on the market in a great variety of forms for a very reasonable price.

METHODS OF USE.

Fig. 1 represents diagrammatically the principles involved in using the photo-electric cell. A battery B has its positive terminal grounded, and its negative terminal connected to the alkali metal S contained in the cell C. A wire is sealed in through the glass and connected through a sensitive galvanometer or other measuring instrument G to earth. If a beam of light be now allowed to fall on the metal surface in the direction of the arrow a current of electricity will flow through the galvanometer.

[1] See *Annalen der Physik*, Vol. 43. p. 225 (1891).

The strength of this current will depend on several things: It increases as the electromotive force of the battery B is increased up to a certain point—at least this is true for most cells obtainable on the market.[2] It depends very greatly on the color (wave-length) of the incident light. But if these two, *i. e.*, electromotive force and color, are maintained constant the strength of the current is absolutely proportional to the intensity of illumination on the metal surface over an enormous range of intensities.[3]

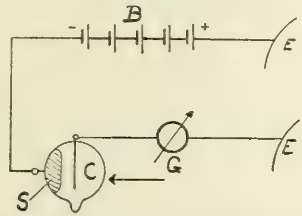


Fig. 1.—Diagram showing the essential connections for using the photo-electric cell. B is a battery, its negative terminal connected to the sensitive metal S. The receiving wire or electrode C is connected through a sensitive galvanometer to earth.

The currents furnished are in most cases comparatively small. Only the higher illuminations (say 20 or 30 foot-candles for white light) produce currents large enough to be measured by a sensitive galvanometer, the connections then being essentially as shown in Fig. 1. These currents are of the order of magnitude of 10^{-9} amperes. For the more common illuminations (say from 0.0005 foot-candles up) a sensitive electrometer is necessary. Although the latter instrument is somewhat more troublesome to handle than a galvanometer, the possibilities of this method of measurement more than justify its use.[4]

One may use an electrometer in either of two ways. If the illuminations are very small the electrometer should be connected

[2] When using E. M. F.'s larger than a few volts the current obtained is due in part to the ionization in the gas.

[3] See paper by the writer, *Physical Review*, Vol. 29, p. 404 (1909).

[4] No attempt will be made here to discuss the difficulties incident to the use of an electrometer. They are by no means insurmountable, and those interested are referred to the various treatises on the instrument.

directly in the circuit as shown in Fig. 2. Here the electrometer Q replaces the galvanometer of the previous connection, and a key *k* makes it possible to discharge or insulate the pair of quadrants to which it is connected. A condenser M may be used in parallel with the electrometer to vary its current sensibility as required. One of the several types of air condensers is most successfully used.

With this set-up the procedure is essentially as follows: The illumination to be measured is allowed to fall on the cell and the key *k* is kept closed until stationary conditions have been reached. *k* is then opened and the rate of drift of the electrometer meas-

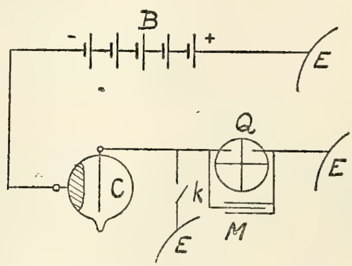


Fig 2.—Showing the method of connecting the photoelectric cell when using an electrometer Q and a condenser M in place of the galvanometer. A key *k* makes it possible to insulate or ground the electrometer.

ured by a stop watch or chronograph. If C is the capacity of the electrometer system, K its constant (*i. e.,* the number of volts necessary to deflect it one scale division) and R the measured rate of drift in divisions per second, then the current I is given by

$$I = C \cdot K \cdot R$$

The capacity used with the electrometer should be such that the rate of drift does not exceed two or three millimeters per second. However, with a good telescope and scale and proper insulation and screening for the electrometer rates of drift as low as a few hundredths of a millimeter per second can be accurately measured.

This "rate of drift" method has its objections, partly due to the fact that a comparatively long time is required for each obser-

vation. The writer has used, as a substitute for it in some cases, the "ballistic" method. This requires in front of the cell a shutter which can be opened, mechanically or otherwise, for a definite time interval. In this method, having previously opened *k*, the shutter in front of the cell is opened, allowing the illumination to fall on the cell for the desired time interval, which must be accurately measured. During this interval the electrometer has been given a certain charge, in consequence of which a permanent deflection is observed after the shutter is closed. If S is this deflection, T the time of exposure, and C and K have the same values as before the current is given by

$$I = C \cdot K \cdot S/T$$

This ballistic method is so useful for such a great variety of laboratory measurements that a special discussion of some of its features seems desirable. Experiment seems to show that at least for moderate illuminations the quantity of electricity discharged by such a cell, subjected to a constant illumination, is accurately proportional to the time of exposure, even when the duration of the illumination is only a small fraction of a second. This makes it possible to make "snapshot" measurements of the candle-power of a fluctuating light source. The magnitude of the quantities concerned are indicated by an experiment by the writer in which a deflection of several centimeters was obtained by an exposure to a Nernst glower of 0.001 second. The glower was two or three feet from the cell. It is unnecessary to emphasize further the possibilities in this direction, for there are numerous experiments where instantaneous candle-powers are desirable under conditions where measurement by eye is almost impossible. Also, one may easily reverse the process and measure a time interval, as for example the speed of a photographic shutter.

When used with this ballistic method the photo-electric cell acts as a time integrator of light intensity, in much the same way as the electrolytic cell acts as a time integrator for the electric current. In other words, suppose it is desired to find the average intensity of a fluctuating light source over a certain time interval, long or short. One would simply have to expose the cell to the

light source for the desired interval and read the resulting deflection. This divided by the time gives the average rate of deflection. By comparing this rate with that produced by a known light source the average candle-power of the first source is at once obtained.

A second method of using the electrometer in connection with the photo-electric cell is to connect the instrument to the terminals of a high resistance, through which the current flows on its way to earth. The principle of this method is of course identical with the method of measuring current by a voltmeter and resistance. Using this device Nichols and Merritt[5] have with great rapidity measured the densities of a series of photographic negatives. While this method has the advantage of giving the current directly by the steady deflection of the electrometer, its use is limited to cases where fairly high intensities are available.

SENSIBILITY WAVE-LENGTH CURVE.

The manner in which the photo-electric current depends on the wave-length or wave-length composition of the incident light is a crucial question when we are considering the application of the photo-electric cell to photometry. Numerous investigators seem to agree that as ordinarily used the cell obtainable on the market has a wave-length sensibility curve which, while agreeing fairly well in shape with the luminosity curve of the human eye, is nevertheless quite different in position, having its maximum much farther toward the violet end of the spectrum. Fig. 3, I and II, shows the sensibility curve as determined some time ago[6] by the writer for one of the cells then obtainable. I is the curve as observed without making any corrections, and II is the result of making the correction for the energy distribution in the spectrum of the source used (curve III). It is seen that the maximum of curve II occurs at about 0.46 μ, although its exact position is left in some doubt on account of the difficulty of obtaining a satisfactory curve for the energy distribution of acetylene, the source used, in the blue and violet. Later experiments by other investigators seem to show that the

[5] *Physical Review*, Vol. 34, p. 476 (1912).
[6] *Physical Review*, Vol. 30, p. 385 (1910).

maximum is even farther toward shorter wave-lengths than here indicated.

This high sensibility to blue and violet constitutes the chief objection to the general use of the photo-electric cell for all photometric measurements. One can readily see that a slight preponderance of blue in the light as measured by eye, would make a vast difference in the measurement by the photo-electric cell, unless the latter measurement were made by use of a very carefully selected set of absorbing screens, so chosen as to give

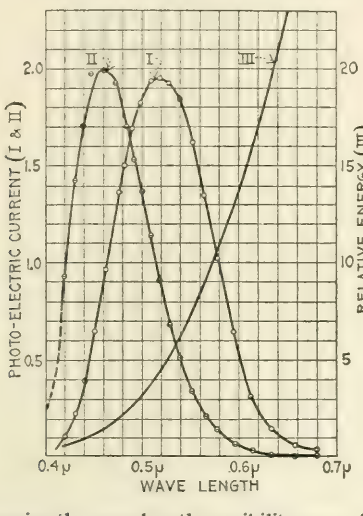


Fig. 3.—Showing the wave-length sensibility curve for a sodium cell. Curve I is the directly observed data. Curve II is the corrected curve, correction for the variable dispersion of the prism used and for the variable energy in the spectrum of acetylene having been made. Curve III shows the energy distribution in acetylene (after Nichols and Merritt).

the cell a sensibility curve approximating that of the human eye. On account of the high absorbing power which such a set of screens must necessarily have, the sensibility of the device would be greatly reduced.

For this reason it seems probable that the most useful applications of the photo-electric cell at the present time must be limited either to cases involving monochromatic or isochromatic light sources, or else to investigations where the actual intensity, pho-

tometrically measured, is of only secondary importance. If, for example, one were making a series of "stroboscopic" snap-shots of an alternating current arc over one cycle, he would not expect the resulting curve to agree either in magnitude or position of its maximum, with the curve obtained by ordinary means. It is possible, however, to isolate any wave-length from such an arc by means of a spectrometer, and by means of the photo-electric cell follow it during one cycle under conditions of intensity and color which would render eye measurement impossible. Furthermore, it is to be remembered that in the blue and violet region, where eye measurement becomes very difficult, the cell becomes most sensitive.

SOME DIFFICULTIES.

In addition to the difficulties previously mentioned, namely, the great care which must be exercised in studying differently colored illuminations and also the fact that the electrometer is somewhat more troublesome to handle than a galvanometer, there exists one great source of trouble due apparently to the fact that a photo-electric cell, even in the dark, will allow a small current to flow if an electromotive force be impressed on its terminals. This seems to be caused by the walls of the cell possessing a resistance which is of course not infinite. This leakage current is fortunately too small to be of serious disturbance when one is measuring intensities of several foot-candles. But when working with lower illuminations of a few hundredths of a foot-candle the leakage current becomes a serious source of error. In fact, it may become much greater than the photo-electric current itself. In any event either it must be determined and a corresponding correction made, or it may be eliminated by charging the cell to such a potential that the difference of potential between the alkali surface and the receiving wire is zero.[7] in which case there is no leakage current. Later cells of improved construction have reduced this difficulty very greatly.

Although the proportionality between photo-electric current and intensity of illumination seems to hold over a very great range of intensities, it is probably not safe to expose any cell,

[7] See paper by the writer, *Physical Review*, Vol. 29, p. 71 (1909).

for any length of time at least, to the very high illuminations (several hundred foot-candles). A cell used by the writer, gave consistent and reproducible results for months when used only on moderate illuminations, until in one experiment it was exposed at intervals, totaling perhaps 30 minutes, to a 2,000 candle-power arc two or three feet away. For weeks afterward this cell gave very erratic readings when used again on lower illuminations, the currents being not only not reproducible, but even varying with a constant illumination, as if to indicate that some sort of instability had been produced by the very high intensity.

In spite of some serious difficulties, the photo-electric cell is being used more and more as a photometric device for special purposes. And the results obtained certainly justify any added effort necessary for its use.

DISCUSSION.

MR. J. L. MINICK: I should like to inquire as to the permanency of the photo-electric cell. If a set of readings were taken as Dr. Ives has described, and the experiment repeated a year later, would the photo-electric cell show any deterioration in that time?

MR. S. L. E. ROSE: I am extremely interested in this paper, and there are one or two questions that I would like to ask; I would like to know if the cell is sufficiently developed to be tried out commercially. The laboratory with which I am connected is ready to help in its application to commercial photometry as soon as the cell has demonstrated its practicability.

DR. H. E. IVES: I think to Professor Richtmyer is due the credit of being one of the first to appreciate the really enormous possibilities of the photo-electric cell. He had papers in the *Physical Review* I think five or six years ago showing the laboratory applications of photo-electric cells. I must say that the photo-electric cell appeals to me as the most interesting subject in photometry. I have been working on it pretty continuously for about a year and I feel as a result of that work, the only criticism I would make of Professor Richtmyer is that he is not enthusiastic enough about the possibilities, and perhaps he is not sufficiently impressed with the difficulties of the cell.

I want to say a word about the sensibility of the photo-electric cell. Last night Dr. Brashear told us about the eye being able to look at the sun for half a second and being able to see a brightness some four quadrillions less. Up to the present time we have had no instruments possessing anything like that range. But in recent work by Elster and Geitel the photo-electric current was measured from illuminations nearly that from the sun down to that from a pin point before a gas flame 20 or 30 feet away. They claim that a direct proportionality holds between illumination and current over the whole of this range. We have something here, therefore, that is going to press the eye pretty closely for range and sensibility.

Now, as to the accuracy and sensibility of the photo-electric cell,—I have made measurement after measurement with the range not exceeding 2/10ths of one per cent., the reading being just as easy as with a first-rate voltmeter. That certainly appeals I think to people who have had to do much photometric work.

A great deal of work has been done since Professor Richtmyer's study upon the theory of the photo-electric cell. It has been found that the maximum sensibility lies in different parts of the spectrum for different metals; with calcium it should be just where the eye is most sensitive. We have a possibility here in that cells can perhaps be made with the color sensibility of the human eye. We might then use the photo-electric cell for colored light photometry instead of having to call on a large number of observers or adopt some other roundabout method.

There is a great deal yet to be done with the cell, however. The question of permanency has been raised and will take time to settle.

Now in regard to the suggestion of putting the cell in front of a moving carriage and running it around. If the speaker would come down to the basement of the laboratory I am connected with and watch what happens to the electrometer when somebody sneezes in the room above, he would realize that there is yet some work to be done before we can carry a cell around on a moving carriage. Nevertheless, the work I am doing with a spectro-photometer demands extreme sensibility.

Where the light is taken directly, without interposing light absorbing instruments it has been found possible to use a portable galvanometer, so perhaps we are not so far from the suggestion as might appear.

As to the cells being on the market, they are on the market; but I would not advise anybody to buy them as they are now being made.

In summarizing this whole question, I want to be very enthusiastic. I really believe that for a great deal of laboratory photometry, especially where lamps of different colors are to be compared, in a few years we will actually be using the photoelectric cell in place of the eye, this provided of course that the simple relationship holds between illumination and current, and that the outstanding question of permanency and uniformity are satisfactorily settled.

FACTORY LIGHTING.*

BY M. H. FLEXNER AND A. O. DICKER.

Synopsis: Ever since the realization of the good and bad effects of illumination, there has always been a great field in factories for better lighting conditions. Better light is as necessary as any sanitary requirements and with these it should rank among the first. Foreign countries have taken better illumination a little more seriously than America has. They have had committees appointed by the government, whose duties are to study the effects of good and bad light upon the general health and report upon methods of bettering conditions. Although the importance of good lighting is generally understood, managers of factories are never willing to make any decided changes from present operating conditions. No matter how forcible the arguments, the first cost of the installation of a lighting system seems to retard any change for better illumination. We desire to show how easily and cheaply conditions can be bettered. We believe that it is just a matter of a short time until the factory manager will understand the great importance of good lighting, and when he does he will not be satisfied until he has a lighting system that is up to the minute.

The aim of this paper is to bring out a few of the most important factors entering into the design or re-design of a lighting system for the factory. It is somewhat discouraging to the illuminating engineer to read article after article dealing with the methods used to raise the sanitary condition of the factory and when all has been read he asks himself "What about the lighting?" Ventilation, cleanliness, devices for safe operation of machines, rest rooms for employees are all discussed, but little or no attention is given the lighting. It is the hope of the authors that this paper will emphasize the fact that factory lighting is a subject dealing directly with sanitation and that it should be considered as such. Why is the lighting important, and whom does it affect? Does it mean a benefit for the central station only, or is it of equal benefit and importance to employer and employee? It seems just as reasonable to ask why should a factory be ventilated or why should it ever be cleaned up. The

* A paper read at the seventh annual convention of the Illuminating Engineering Society, Pittsburgh, Pa., September 22-26, 1913.

owner or manager would immediately say: "If I do not ventilate the work rooms the operators will become dull and lose interest in their work." Regarding his lighting conditions he knows naught and his answer to a question relative to his lighting condition, would very likely show that he never gave it much thought. This is just the man who needs some information regarding lighting. He does not realize that just as many of the headaches are caused by poor lighting in factories as there are from poor ventilation. This is not intended to belittle the importance of good ventilation, but is only mentioned to emphasize the fact that general improvement of condition does not end when a factory has been properly ventilated or properly cleaned. It does not end until the lighting as well as these have been considered. One is just as important as the other, since injury to the eye from poor lighting causes suffering equal to or even greater than the sickness caused from poor ventilation. In considering such vital subjects this country seems to be far in the rear of countries on the other side. We're behind the times, so to speak, and have not kept pace with France, England and other European countries, who are protecting their workmen, along these lines.

In 1912 the French Government appointed a Committee on Hygienic Aspects of Illumination, composed of prominent physiologists, oculists, engineers, physicists, and inspectors of factories. The main objects of this committee are:

(a) To study, from the standpoint of general health and its effects on vision, the various methods of artificial lighting now used.

(b) To determine the composition and quality, from a hygienic standpoint, of the different combustible illuminants, and to examine the effect of prejudicial gases and the amount of heat developed thereby,

(c) To fix a certain amount of artificial illumination to the normal requirements of vision.

(d) To study the most practical methods of measuring illumination.

(e) To formulate recommendations governing the best means of applying customary methods of lighting to the chief varieties of industrial operations.

(f) To present to the Ministry a report on the subject of short sight and impairment of vision, and on the best methods of guarding against the cause of myopia.

It is the result of the investigations of such committees that awaken the mind of the manufacturer to the necessity of providing good lighting.

The first question that might be asked is: What is good illumination, or what is practical illumination? Can we spot a unit or cluster here or there, put a drop light over the working places in a slip-shod sort of manner and expect to be satisfied with the results; or, is it a matter of knowing what to expect from each means of illumination and its corresponding reflector and to fit in these units to meet the conditions in the factory? Our common sense dictates that it is the latter. Our experience teaches us that the problems involved are often difficult of solution and that we must have definite ideas about correct illumination before we attempt to accomplish satisfactory results.

One authority defines good lighting as any system which does not attract attention to the means of illumination, or cause one to wonder how the illumination was obtained. An analysis of this yields the following requirements for good lighting:

First, that sources of high intensity must not be in the field or ordinary vision; second, that the amount of light be sufficient for the work to be done; third, that the distribution of light be uniform or as nearly so as possible, and fourth, that the color be pleasing to the eye. By adhering to these principles, we will not go far wrong in laying out lighting installations, whether for factory or for home, being assured of good illumination.

The value of good illumination should not be under-estimated. Some are contented to travel along in the old time worn ruts and to leave well enough alone. Many believe that as long as there is light, whether good or bad, the question of lighting is settled, and that the results obtained are as good as any light could produce. This is the wrong idea, but nevertheless it is entertained by many managers and officials of factories under whose jurisdiction the question of lighting comes; however, they must realize sooner or later the value of better operating conditions, produced by good lighting. To do work, light is necessary; with

a little light, a little work can be done and with more light more work can be accomplished. This is very evident, and it is easily seen that no matter how a shop is lighted, if it can be better lighted, better or more work must result, up to a definite per cent. increase in efficiency of the workman.*

What if our Mr. Official had to go home to a dimly lighted dining room? How would he like to read a paper which necessitated straining his eyes, or shave in little or no light, with his face very near the mirror and his eyes fixed in a staring position. It would not be very comfortable and he could hardly give himself much of a shave; yet under these conditions he expects his men to work, to turn out good work, and make his factory an efficient one.

There are such things as good and bad lighting installations, and to the progressive official the best should not be too good for his men. However, the initial cost is given first consideration and is the one stone that lies in the path of all changes, and therefore we can but sum up the reasons why it is worth every cent that is asked in making a lighting installation a good and efficient one.

Statistics have shown that, as the result of better illumination and a decreased strain on the eye, the physical condition of the workmen is better, they are better satisfied, imperfections in the work have been materially decreased and the factory output increased from 8 to 15 per cent.

Not only is the general physical condition of the workman improved by better lighting but his liability to accident is greatly decreased. Recently published statistics show that during those months of the year in which artificial lighting must be used, there occurs a greater number of accidents than in the light months. The saving made by good lighting in this line alone will often more than repay the extra cost of installing and maintaining the lighting system. It has been said that a man who is obliged to keep one eye on the danger points of a machine has only one eye left to operate it. This is unquestionably true and consequently a machine must be made absolutely safe. The factory manager usually tries to accomplish this by putting a guard rail

* See *Electrical World*, page 319, Feb. 10, 1912.

around the danger points or else enclosing them entirely. This seems about as reasonable as putting a rail around a hole in a street without placing a lantern on it. Protected machines still cause accidents and will continue to do so until the proper light is provided and the danger points brought well into view. Accidents are becoming more expensive each year and disregarding all humitarian arguments an owner can no longer neglect to protect the operators from accidents. Good light is the most effective protection that can be provided and only carelessness on the part of the employee will incur accident under these condi-

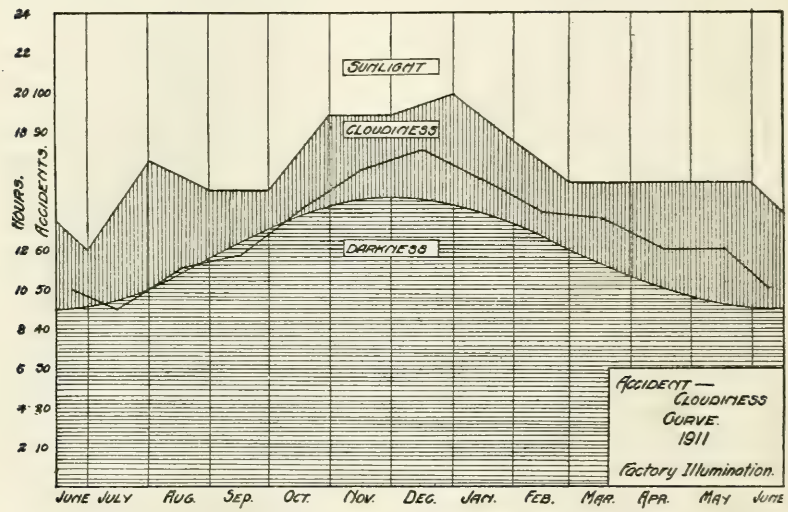


Chart showing accident and cloudiness curves.

tions. "It costs us a lot of money, but it has paid for itself in less than a year" said one manufacturer. What more can an owner want? Certain courts have held that failure to illuminate danger points constitutes "contributory negligence." Germany, Austria, Holland and France, realizing the importance of good lighting conditions, have included lighting in their codes for factory inspection of health and safety. The accompanying diagrams shows that the maximum number of accidents occur during the time in which artificial light is used. It is interesting to note that the accident curve is almost a duplicate of the cloudiness curve.

In the installation one must take into account the position of the machines, the work that is done, the location of posts, the windows, and in fact every condition which may in some way cause deep shadows and bad illumination. The scope of this paper does not allow us to enter into any detailed account of layouts. As stated in the introduction, we are only attempting to emphasize the necessity and advantage of better factory lighting.

Good factory lighting is not beyond reach; it is not something that one can only wish for. It is a material thing and may be had for the asking.

A great many bad installations can be made good ones by two inexpensive methods; either re-locating the units and the addition of proper reflectors, or in some cases by replacing existing units with some of the modern efficient type now on the market. It is not hard to show that the new system will, within a given time, pay for itself, and in a great many cases save money over the operating and maintenance expenses of the old system.

Assume that the owner of a factory depends solely upon the profits of the work his employees turn out. An equation expressing output must involve the personal equation of the men and there must be a certain personal efficiency of each man under every condition in which he works. If a high priced man is placed under poor working conditions his work will be no better than the low priced man under good conditions. A manufacturer will usually buy a labor saving device or a machine with which his workers can turn out more or better work, and he will supply his employees with tools of the highest grade steel and have men to keep these tools in the very best condition; but he often absolutely ignores the personal efficiency of the operator and the conditions under which he must work. He does not usually see all the methods of making the man as perfect as his tools. In other words, more time and thought is given to the tools than the operator. What good is a perfect tool or machine if the operator can hardly see what he is doing with it? This sounds ridiculous, of course, but it is true of many a factory to-day. For instance, a manufacturer purchased a certain machine at a cost of $18,000.00 and paid a high priced man of

long experience to operate it. Yet this owner could not see his way clear to spend $19.00 in order that this high priced operator would not have to take the product twenty feet away to the window to caliper it. This shows how little the owner considered the personal efficiency of his men.

The cost of illumination as compared with an operator's salary is very small and insignificant; in fact, so small that the manufacturer can not see it at all. The following data, taken as average conditions, shows this.

If a 100-watt lamp is assumed for each man and that it burns 3⅓ hours per day for 300 days, the following is derived:

Cost of lamp (Commonwealth Edison Co. renewal)		$0.00
Cost of reflector		1.00
Cost of wiring per outlet		4.00
Total first cost		$5.00
Interest on investment 6%	$0.30	
Depreciation at 12½%	0.63	$0.93
Power at 5 c.		5.00
Cleaning at 3 c. per mo		0.36
Renewal of lamps		0.00
Total		$6.29

Wages for 10 hours a day, 300 days, may be assumed to be $1,000.00. Thus the ratio of the cost of furnishing illumination to a man under the above conditions would be (overhead expense not included,), $\frac{6.29}{1,000}$, or 0.629 per cent.

The following mathematical deduction shows what good lighting would mean to a factory upon the installation of such a system. Taking an area of 30,000 square feet with an average of 0.75 watt per square foot, a connected load of 22,500 watts would result. Figuring the installation with 250 watt units an estimate of the first cost is surprisingly low:

90 250-watt outlets at $3.50	$315.00
90 fixtures at $1.25	112.50
90 reflectors at $1.00	90.00
90 lamps (Commonwealth Edison Co. renewal)	0.00
Total	$517.50

Let it be supposed that this factory turns out a yearly business

of \$250,000 and that 33⅓ per cent., or \$83,333.33 of this business is done under artificial light. Assuming a conservatively 5 per cent. increase in output as the benefit due to good lighting, the business is then increased \$4,166.67. If there is a profit of 20 per cent. on this output a credit of \$833.33 is derived, which is considerably more than the installation cost.

As further proof of the low installation and operating costs of good lighting the following data are submitted from a table compiled from actual figures on three trial installations in a large factory with lamp prices, etc., revised so as to be up-to-date.

100-WATT TUNGSTEN LAMP.

30 reflectors at 92 c.	\$27.60
Wiring at \$3.22 per outlet	96.60
30 lamps at 0.72	21.60
Total	\$145.80
Interest on investment at 6%	\$8.75
Depreciation at 12½ %	15.55
Renewals at 30 × 900/1000 hrs. × 0.72	19.44
Energy 3000 × 900 hrs. × 1.1 c.	29.70
Labor (cleaning 30 × 0.63 × 20 c.)	3.78
Total annual cost	\$77.22

These figures are derived on the assumption that good factory lighting will necessitate a 100-watt lamp for 100 square feet of working area required by an ordinary workman. With these assumptions the following information has been tabulated:

Total working hours 300 × 10	3000 hours
Total lighting hours 300 × 3⅓	1000 hours
Average cost of labor per hour	35 cents

Labor—

3000 hours at 35 c.	\$1050.00

Light—

Cost of 100-watt tungsten lamp (Commonwealth Edison Co. renewal)	\$0.00
Cost of metal reflector (trade price)	1.00
Average. cost of wiring per outlet	4.00
Initial investment per outlet	\$5.00

Interest at 6%	0.30	
Depreciation at 12½ %	0.63	0.93
Cleaning 12 mo. at 3 c.	0.36	
Lamp Renewals (Maintenance)	0.00	0.36
Energy 100 K. W. H. at 5 c.		5.00
Annual operation cost		6.29
Annual wages for one man		$1050.00
Cost of light in per cent. of wages		.6

When reduced to cost per hour based on 3,000 working hours per year, one finds:

Labor per hour	$0.35
Light per hour	0.00629
Cost of light per day	0.02096
Cost of labor per day	3.50

These figures go to show that the cost of good lighting is a very small portion of the cost for a man's time; in fact, if good lighting would save five minutes of a man's time per day a material gain would be experienced.

By following this form, any local conditions causing different prices than those given can be substituted so that a comparative figure can be obtained for any particular locality.

The cost of maintenance of tungsten lamps and reflectors is stated as follows in vol. 1 of the 1911 *Proceedings* of the National Electric Light Association.

	Per cent.
Renewals of lamps	75
Renewals of broken reflectors	3
Changing reflectors for washing	16
Labor for washing reflectors	2
Additional indirect charges	4
	100

This data is from experience with an installation of between 7,000 and 8,000 lamps and reflectors.

With the available units, it is impossible to pick out one lighting unit and say that it can be used for all conditions. There is no one cure for all evils. Individual conditions enter into the problem and the resulting unit must be best for the conditions presented. The most important qualifications are the following:

Efficiency; color; quality; arrangement of machines—processes; adaptability; special architectural features; and available hanging height.

The best unit to use will be the one that best fulfills these requirements. Each light source, whether gas arc, individual gas, electric incandescent, arc or vapor lamps, has its definite field in factory lighting. Usually where one should be used the others will be less satisfactory. It is hard to convince the owner that the cheapest is not the best, for he usually wants light only, and often will not pay for the necessary equipment to produce illumination. The problem of which one to use depends upon the class of work to be done under it, as each lamp has certain characteristics that argue for and against its use.

The last few years have brought great developments in the arc lamp. The flame arc of long life, furnishes a light source of high candle-power and low maintenance cost. When the white light-giving carbons are used the light emitted is of good but rather variable color. This lamp should never be used in the normal range of vision. It is best adapted to factories with high ceilings.

There has been considerable talk about the harmful ultra-violet rays emitted from arc lamps. These rays are no doubt given off to a considerable extent, but they are lost in the inner globe. Therefore this characteristic should not be an argument against the arc lamp. The greatest objection to this light source is its unsteadiness, and for fine accurate work a more steady unit might better be used.

The mercury-vapor lamps are particularly well adapted to certain kinds of manufacturing. The peculiar color together with the high visual acuity renders them very useful. A large clothing manufacturing concern has recently replaced enclosed arcs with vapor lamps in pressing rooms. It is remarkable the way scorching can be detected under this lamp while if a tungsten lamp is used the scorch is not so noticeable. The vapor lamp has met with decided approval in this kind of work. This goes to show that the unit used should depend entirely upon the work to be done.

In installations where the tungsten lamp is the source of light, too much emphasis cannot be put on the subject of cleaning. The manufacturer would not allow his operators to leave their machines at night without cleaning them; the floors are cleaned and each morning the factory is found in tip-top shape. Why? So that the work may begin under the best conditions, all working toward an increase of output. In other words, everything but the lighting equipment is systematically taken care of. The owner knows that the time and money spent in cleaning a machine is well spent, and yet that which has a greater effect on the efficiency of the operator is left to accumulate dirt from day to day and in many factories from month to month.

In general, it is best to have the light source as high as possible above the working plane. If it is out of reach of the worker, he cannot handle it and thus it will be free of a coating of oil or other dirt. Truly enough, certain machines require drop cords in setting up the work or changing the dies, but few machines actually need drop cords during their operation. One big railroad shop in Chicago has adopted Cooper-Hewitt lamps for general lighting and drop cords are checked as any other tool. In this way they are taken care of and are not used except when necessary. It has been our experience that the worker will use a drop cord as long as he has one in front of him.

The first move for efficient lighting is general illumination, where possible, doing away with the drop cord or as above stated, making the drop cord a working tool.

There are many combinations of efficient lighting systems; in fact, it is a subject of its own, so that we will not attempt a discussion.

Realizing the general disregard of good lighting as a necessary and important part of the factory equipment, and not overlooking the attractive lighting load of this class of service the Commonwealth Edison Co. of Chicago decided to make a proposition covering lighting installations for factories.

As has been stated, the first cost of the installation is too often the only obstacle, and therefore this company decided that the first way to make such a proposition attractive was to do away with the first cost. To insure most efficient operation the com-

pany includes in this proposition the cleaning and renewing of all fixtures and lamps.

The Commonwealth Edison Company's proposition is as follows:

The customer is asked to sign a contract for a period of twenty-four consecutive months. After the expiration of this period, the wiring and fixtures become the property of the consumer.

Charges for this service are made up on the following basis: rental charge, maintenance charge and electricity charge.

Rental Charge.—The rental charge is twenty-five cents per fixture per month, allowing the consumer to use either 100, 150 or 250-watt units in each fixture. At the end of the two year period this equipment becomes the property of the consumer and this charge is discontinued.

Maintenance Charge.—The consumer pays the company twenty-five cents per fixture per month, except during the months of June, July and August. At the end of the two year period, the consumer may elect to discontinue paying this charge and take care of this equipment himself.

Electricity Charge.—For this service the consumer pays our regular schedule A rate which is ten cents net per kilowatt hour for the first thirty hours use of the maximum demand per month and five cents net per kilowatt hour for all energy used in excess of this amount.

The fixture supplied under this contract is one that was especially designed for this class of service. It consists of a shallow reflector with a collar containing a lock socket; the conduit serves as a stem. The reflector is so designed that the filament does not extend below the bottom of the reflector. Photometric curves show extensive characteristics. The idea throughout was to make a reflector that was efficient, plain, and easily cleaned.

The Commonwealth Edison Company confidently expects to install 10,000 of these fixtures within the next year, and a report of the first few months gives reason for the confidence expressed.

In summing up we believe that the campaign for good fac-

tory lighting has just begun and that the best argument in favor of better illumination is a statement showing the benefits derived from an efficient lighting system and the experiences of others.

Even a hasty reconsideration of the arguments presented in this paper demonstrates the tremendous scope and possibilities along this line. There is no longer any excuse for poor lighting; the necessity, the practibility, and the economy of good illumination have been demonstrated beyond question and if the strides in this direction which have been made in the recent past may be taken as an index of those which will be made in the future, there is no doubt that very soon the time worn phrase "a badly lighted shop" will have disappeared from the vocabulary of those connected with the lighting industry.

We believe that if a fair and broad-minded manufacturer will but figure out in a common sense way the merits and necessity of good illumination, he will be converted to its use in a short time. If his own figures do not satisfy him, let him consult those who have been far-sighted enough to go ahead with his better sense dictation and be shown, if necessary, the truths of the above assertions. He will realize sooner or later the needs of his men —better atmosphere, lighter and cleaner shops, and proper illumination.

DISCUSSION.

Mr. H. A. Reid: On the seventh page of the paper there seems to be a discrepancy with regard to the assumed cost of wiring per outlet, the reason for which is not apparent. In the first table the cost for 100-watt lamps is given as $4.00, and in the second table $3.50 is used as the cost for 250-watt outlets. It would seem that the cost of wiring should be no higher for the 100-watt than for the 250-watt; rather should the reverse be the case. In the actual installation cited on the eighth page the cost per 100-watt outlet was $3.22.

The assumed depreciation rates appear also to vary. In the first example on the seventh page, 12.5 per cent. is taken to apply on lamps, reflectors and wiring; in the second example the rate on wiring is reduced to 5 per cent. If the wiring is properly installed, the latter value will probably be about right.

Mr. R. B. Ely: I think the central stations and gas companies particularly the smaller companies, should encourage the introduction of illuminating engineering departments. The up-to-date companies can effect a saving and improve the lighting conditions in factories, stores, etc., and of course where there is gas or other means of illumination employed, the advice of the engineering department when followed will frequently offset the expenses of the improvements. In numerous instances it takes a week to lay out an installation. In one case it cost $1,200 to equip one floor for trial, but the effect and saving was so good that they went ahead and wired the whole factory. That is not an exceptional instance.

Mr. G. H. Stickney: I want to emphasize the importance of industrial lighting to the central station. I have felt in the past that a great many central stations have considered industrial lighting as an undesirable load and have not awakened to the possibilities of it. I think that now that the Commonwealth-Edison Company, one of the most enterprising companies of the country, has pointed out what they are doing, we may hope that in another year other central stations may also contribute useful data.

Mr. G. W. Roosa: In the second paragraph on the tenth page is this statement: "When the white light giving carbons are used the light emitted is of good but rather variable color." In factory lighting where flame carbon arc lamps are to be used the bays are usually wide and high. Such installations often include a number of these lamps; for instance, four or more, or possibly a multiple of four. If there is a variation of candle-power from any one lamp it can not be altogether objectionable because the average variation from several lamps will be slight, due to the fact that variations in individual lamps seldom occur simultaneously. Flame carbon arc lamps are usually equipped with diffusing glassware of some kind when placed within the field of vision, or at a position approximating it. Equipped with proper diffusing glassware this type of lamp has an intrinsic brilliancy of about 15 candle-power per square inch. On the other hand, most incandescent lamps are used with clear bulbs instead

of frosted ones, and I believe the intrinsic brilliancy is about 1,000 candle-power per square inch.

Mr. E. W. Lloyd: It occurs to me that the benefit to be derived by the manufacturers, central stations and illuminating engineers from the development of good lighting in factories would put more money in their pockets than from any other line. We have heard a great deal about the developments of motor drive in central station service in factories all over the United States. The recent United States census shows some very remarkable figures relative to that growth—several hundred per cent. in 10 years. I believe the growth will be greater in the next 10. Strange to relate, however, the development in factory lighting has been very, very, slow; at least it is slow in many of the cities that I am acquainted with. There are many motor equipment in factories, but an examination of the installations of lighting in those factories is a shock to a man who spends any time thinking about the subject of illumination. It was because of that condition in Chicago that we decided to help increase this business by offering to finance the installation of these lighting systems.

Manufacturers are becoming interested in the proper design of reflectors and fixtures, and I believe there is a great deal being done in this direction. All manufacturers of fixtures are not up to date. Some of our trouble comes from the different schools of illumination, the different methods of accomplishing results; but I don't think it is necessary to dwell upon that. Every effort toward better illumination is going to help the whole matter along.

I merely want to say in closing that the central stations can do more business at the moment, by devoting energy to the illumination of factories, in my judgment, than in any other way.

Mr. H. C. Chapin: It is important to emphasize that tests be made of working conditions; for instance, a yellow flame carbon, already of higher efficiency than a white flame, will show a still greater comparative efficiency in a smoky atmosphere, because the yellow light penetrates the atmosphere better than the white.

Mr. S. L. E. Rose: It may be of interest to know that there

have recently been developed reflectors for the flame arc, which give intensive and extensive distributions and also an angle reflector. A 6.5-ampere direct-current, multiple, flame lamp with yellow carbons and an intensive reflector gives about 10,000 lumens in the zero to 60 degree zone. This is equivalent to about 14 lumens per watt, and applies where the lights necessarily hang high. The extensive reflector on the same lamp gives approximately the same number of lumens in the zero to 60 degree zone.

MR. M. H. FLEXNER: I wish to say that our information as to the increase in output, resulting from better lighting conditions, was obtained from a pamphlet on factory lighting by Mr. G. C. Keech and from the plant of Wilcox and Parker of Chicago. The latter firm reported about a 10 per cent. increase in output.

Our remarks on the flame arc lamp were based upon our own observation. Flaming arcs should not be hung low, and by that I mean hanging heights of 10 and 12 feet. In such installations bright spots are plainly visible, proving that the lamps are not lighting as large an area as they would with higher hanging. The City of Chicago has recently passed an ordinance which requires that all arc lamps in the down town district be hung 23 feet, and in the outlying districts 21 feet. There are some streets lighted with flaming arcs and which are hung about 10 feet high. In riding in the street cars on those streets one finds the glare from these lamps very disagreeable, and riding through the alternate dark and light spaces, soon fatigues the eye. This, of course, is a little foreign to our subject, yet the results would be somewhat similar in both installations referred to.

The discrepancy in costs of wiring per outlet, given on the seventh and eighth pages, referred to by Mr. Reed is due to the fact that one is an actual and the other an average cost. The discrepancies in depreciation, etc., are explained by the fact that conduit was used in one case and moulding in another.

MR. H. H. MAGDSICK: This paper brings to our attention the very low cost of lighting compared with the total cost of production in industrial plants. Recently we obtained com-

plete data for a cold-roll mill lighted uniformly to an intensity of two foot-candles, which made it possible to read micrometers with ease in every part without any auxiliary drop lamps. The total cost of operating the lighting units, including the fixed charges on the equipment, renewal and maintenance of lamps and the energy, is only one one-hundred-fiftieth of the cost of labor during the hours of darkness. In other words, supplying all the light that is desired in this department costs no more than furnishing one helper for each 150 men. The difference in cost between poor illumination and adequate lighting is, of course, still less. Any system that would enable this mill to be operated at all would, we will say, require one-half the expense; the difference between poor lighting facilities and the very best illumination is, then, secured at a cost no greater than that of supplying one helper for 300 men. And the cost of labor is only one item in the cost of production, often no more than 20 per cent. of the total. If to it are added the fixed charges on the plant and machinery, the cost of power and expense of supervision, administration, etc., one obtains an idea of how comparatively insignificant is the cost of proper illumination.

The iron and steel industry offers an interesting example of recent developments in plant illumination. President Parkhurst of the Association of Iron and Steel Electrical Engineers has given permission to quote from a paper that will be presented before the convention of that association now in session. The data contained therein were compiled from reports submitted by nearly one-half of the companies represented in the A. I. & S. E. E. It will be recalled that the members have for several years interested themselves actively in illumination matters and were among the first to co-operate with this society.

From the reports, it appears that during the past two years the wattage installed in lighting equipment throughout the plants has decreased slightly, about 5 per cent. but the average intensity of illumination has been raised to about 135 per cent. of the former value. This increase was secured by replacing obsolete equipment with more modern units. Thus, while two years ago about 58 per cent. of the connected lighting load was in

carbon arc lamps, for the most part of the 220-volt type, and less than 8 per cent. was in high-efficiency incandescent lamps, the carbon arc lamps have now dropped to about 34 per cent. and the high-efficiency incandescent units have been increased to an equal wattage. The carbon incandescent lamps have not been decreasing as rapidly as the arcs due, it appears, to the fact that up to the present time the intensities of general illumination provided have proved insufficient to warrant discontinuing the use of drop lamps for local lighting. Where complete modern systems have been installed, however, the reports show that auxiliary units have in practically all cases disappeared. These changes represent the important developments in the lighting equipment of the steel mills. The flame arcs, mercury-vapor lamps, etc., remain a small percentage of the total.

According to the data submitted, the 76 plants represented in the A. I. & S. E. E. still have about 24,000 kilowatts connected in carbon arc and carbon incandescent lamps. If these were replaced with modern equipment, the illumination instead of being 135 per cent. of the average value of two years ago, would become 235 per cent. It is costing the plants about $1.500,000 annually to operate this obsolete equipment. At a conservative estimate, fully two-thirds of this amount, or $1,000,000, is wasted annually in view of the higher efficiency of the modern equipment with which it might be replaced. The fact that when changes are made this wasted amount will probably be expended in the operation of modern lighting systems in order to secure higher intensities of illumination, serves merely to multiply the loss, for the gain in the output of the mills and increased safety of employees is in practically every instance far greater than the cost of illumination.

HOSPITAL LIGHTING.*

BY WILLIAM S. KILMER.

Synopsis: Short-comings in hospital lighting are too well known to need mention; ordinary illumination devices for hospitals fail to give the proper quality and distribution of light. This paper treats solely of the lighting of the two most important quarters of the hospital, viz., operating-room and wards, and describes practical fixtures for the solution of the various problems. Although written from an engineering standpoint the paper is based on intimate knowledge of hospital conditions derived from the author's two years' concentrated work in this field.

The modern hospitals of to-day are undoubtedly models of elegance and hygienic forethought and this high degree of perfection has been reached by experience in overcoming specific difficulties and conditions as they are encountered.

For some unexplainable reason the question of proper artificial illumination has received little or no consideration, thus greatly lowering the efficiency of the splendid service characteristics of these institutions.

Light like any other form of energy may become an agent of destruction or a minister of health, precisely in accordance with the wisdom shown in its application, and it is the duty of the professional advisor, whether he be architect or engineer, to understand these particular conditions before he can pretend to satisfactorily specify a lighting system.

The operating rooms and wards which are the most important parts of a hospital naturally present the most difficulties, and it is the object of this paper to treat particularly the lighting of these two areas.

OPERATING ROOMS.

The operating table should have, on account of the large amount of surgical work performed at night, a system capable of concentrating on the field of operation an illumination intensity of not less than 25 foot-candles, preferably higher, and approximate

* A paper read at the seventh annual convention of the Illuminating Engineering Society, Pittsburgh, Pa., September 22-26, 1913.

the tonal value of daylight. The equipment should be designed along plain smooth lines, thus avoiding the septic risks of dust collections and rendering it easily and thoroughly cleaned. When it is necessary to suspend a fixture in close proximity to the table and when over 250 watts are consumed by the equipment,

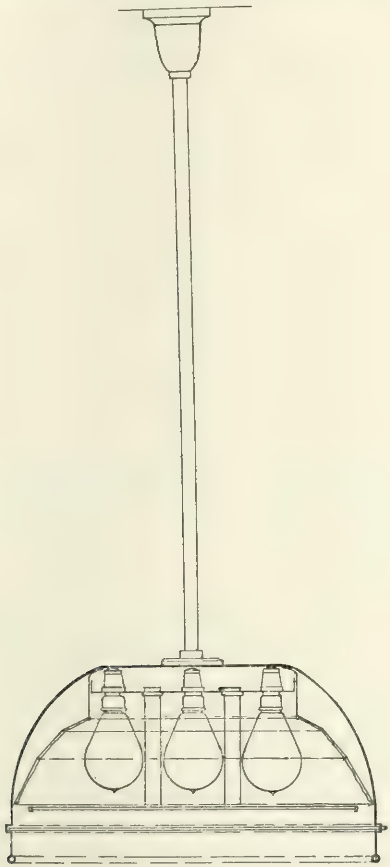


Fig. 1.—Ventilated operating fixture, using six 100-watt tungsten lamps.

it is most important that the heat generated by the lamp be directed away from the patient and the head of the surgeon.

Fig. 1 illustrates a unit of the above description, which is designed for six 100-watt tungsten lamps and when suspended 6 ft. 6 in. (1.98 m.) from the floor to lower edge of the frame,

an average illumination of 40 foot-candles is distributed over the table. By the addition of a ball and socket joint this equipment may be adjusted to suit any form of operation.

To reduce the heat generated by the lamps to a minimum, the fixture has an ingenious arrangement of double glass slides, by

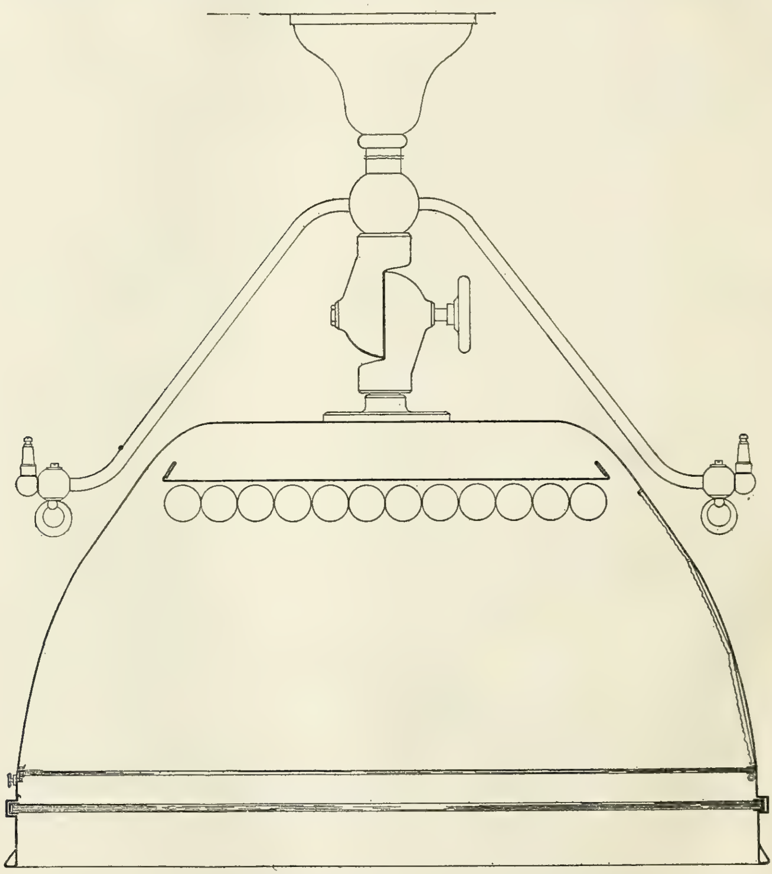


Fig. 2.—Ventilated operating fixture, using eight 35-watt double base tubular lamps, with emergency gas attachment.

which a forced draft is created by the heating, and consequently raising the air between the glasses, the heated air passing out of the fixture through the vents at the top. This syphon arrangement is often assisted by the use of suction pumps.

Under actual working conditions, temperature tests show the

following results, with mercury 9 in. (22.86 cm.) below the lower plate glass:

	Degrees Fahrenheit
Temperature of room	76
After one hour burning with slide	83
After one hour burning with no slide	94

Fig. 4 shows an equipment of this character installed in the Post Graduate Hospital, New York City.

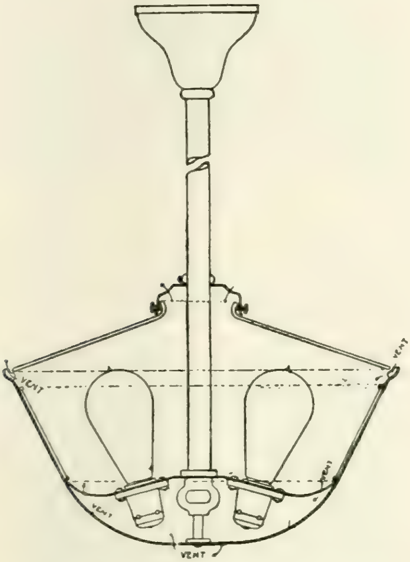


Fig. 3.—Detail of dustless indirect ward fixture.

Fig. 2 is a unit built on the same general principles, but designed for a double base tubular lamp with a straight filament. This fixture with eight 35-watt lamps gives an illumination equal to the previously described unit, but over a smaller area. The elimination of the excessive heat is as follows:

	Degrees Fahrenheit
Temperature of room	78
Fixture after one hour burning with slide	81
Fixture after one hour burning with no slide	87

In both of these fixtures the mirrors forming the reflecting surface are so arranged that the field in front of the surgeon's hand is always free from shadows, no matter in what position it may be.

The new concentrated filament lamp, with a distribution of light given in the following table, has made possible another form of lighting the operating table, *viz.,* adjustable reflectors capable of powerful concentration. (Electrical Testing Laboratories report on 100-watt concentrated tungsten-filament lamp referred to):

Angles degrees	Candle-power
155	66.0
145	72.0
135	75.0
125	75.5
115	76.0
105	76.5
95	74.0
90 Horizontal	74.0
85	76.0
75	78.0
65	80.0
55	81.0
45	82.0
35	78.0
25	72.0
15	64.0
5	56.0
0 Nadir	55.0

Fig. 6 is an all metal reflector so designed that the light is confined approximately to an area 5° either side of the vertical and should be suspended stationarily directly over the table, about 8 ft. (2.44 m.) from the floor. When it is so installed with a 100-watt concentrated filament lamp a satisfactory distribution is given for all operations requiring a powerful downward distribution. To protect the eye of attendants and surgeons, when raised from the field of operation, a series of metal bands may be inserted as shown in the drawing.

The following photometric values apply to this unit:

Fig. 3a.—Exterior of dustless indirect ward fixture.

Fig. 4.—Fixture shown in Fig. 1 installed over operating table in Post Graduate Hospital, New York City.

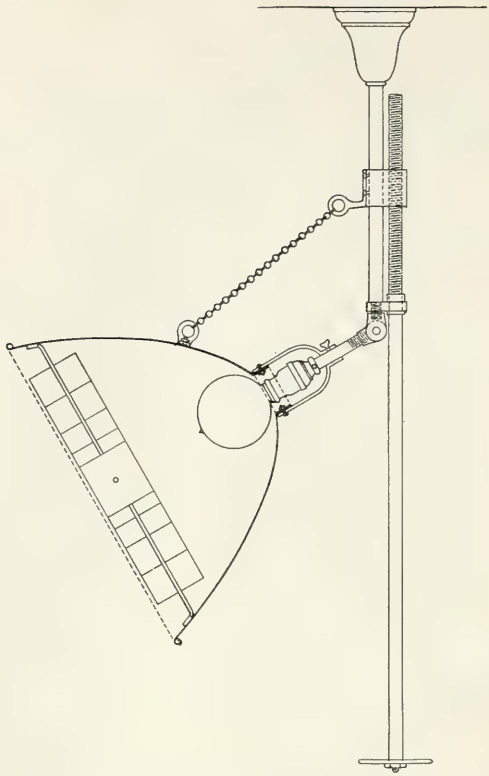


Fig. 5.—Adjustable parabolic reflector for powerful concentration.

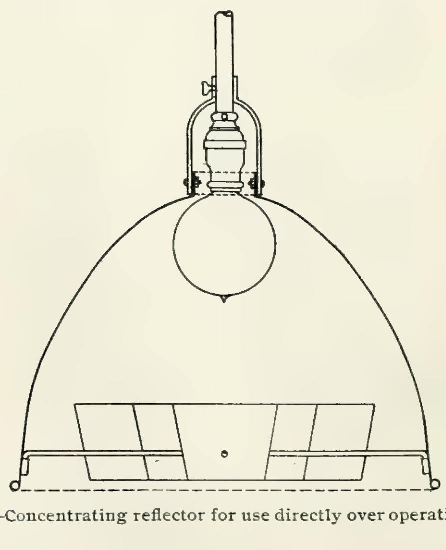


Fig. 6.—Concentrating reflector for use directly over operating table.

Angles Degrees	Apparent Candle-power Without bands	With bands
0 Axis	2,160	2,160
5	2,250	1,800
10	430	380

Photometric distance 30 ft. (9.144 m.); measurements made in a single plane through the reflector axis.

Abdominal and pelvic operations require a penetrating beam of light. Fig. 5 shows a parabolic all metal reflector 18⅝ in. (47.59 cm.) in diameter, adjustable to any angle. This equipment should be attached to a rigid support about 12 ft. (3.66 m.) from the floor and 12 ft. to 15 ft. (3.66 to 4.57 m.) to the rear of the table with the adjusting rod of sufficient length to be easily reached; when so installed a powerful beam of light is directed over the shoulder of the surgeon directly into the field of operation.

The photometric values of this unit are as follows:

Angles Degrees	Apparent Candle-power	
0.0	9,600	7,940
2.5	8,330	—
5.0	2,000	—

Photometric distance 30 ft. (9.144 m.); 100-watt concentrated filament tungsten lamp, measurements made in a single plane through the reflector axis.

It is quite apparent that with this distribution there need be no fear of insufficient and poorly distributed light. These equipments may also be mounted on adjustable standards, thus having an equipment for all emergencies which are so often encountered.

Some hospitals object to any suspended lighting equipment in the operating room; this usually applies to rooms having a skylight, and provided sufficient head room is available a satisfactory system may be designed by placing a series of reflectors around the edge of the skylight. These reflectors may be so designed that the maximum reflection falls at a point directly over the table. This scheme is likely to be more satisfactory than an attempt to illuminate the entire skylight so as to provide a sufficient amount of light for an operation in any part of the room. The latter scheme would necessitate a very large consumption of energy.

WARD LIGHTING.

In the wards the evils of glare have to be most carefully avoided, as influence of glare upon the retina of the debilitated or depressed is usually followed by serious results.

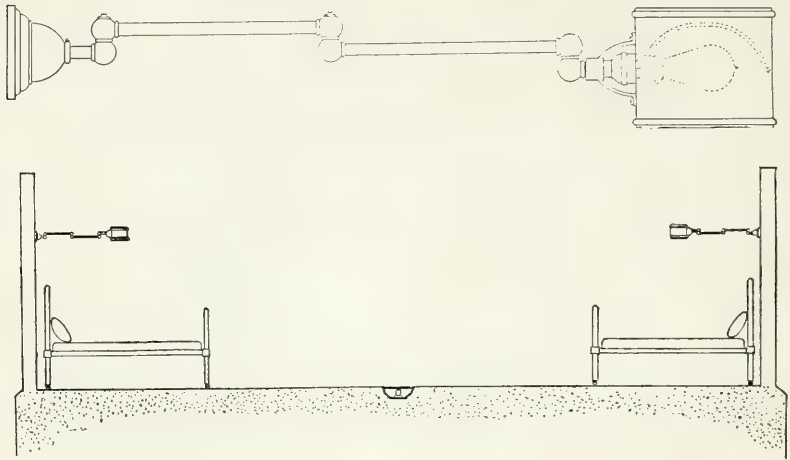
The average ward of twenty beds should be provided with two kinds of illumination, general and localized. The general lighting should not average more than one foot-candle and should be obtained from either a totally or partially indirect source, so arranged that violent contrasts are entirely eliminated. It is advisable that the ceiling be treated with a flat white or French zinc surface and the walls in a slightly darker tone, such as buff or French gray.

The fixtures must be of special design and the same hygienic conditions apply as in the operating room, *viz.*, elimination of dirt and heat. Also that portion of the light which is diverted to the ceiling must be evenly distributed without spots and streaks. The exterior finish should be a restful color such as green enamel or matt nickel. This will not give a violent contrast, and will overcome the sameness of the white enamel finish which many fixture manufatcurers seem to think is necessary for hospitals.

Fig. 3 shows a form of indirect fixtures which has met with great success in ward ligthing. It can be made for any number of lamps up to six. The interior is lined with a series of mirrors set at any angle to insure an even distribution of light over the ceiling. The angle at which these are set depends on the distance between outlets and the size of the ward. Over the top of the bowl is set a thin blown glass plate which may be easily raised for lamp renewal by means of the sliding metal holder, and which renders the interior of the fixture dust and dirt proof. Ventilation is accomplished by means of vent holes at the bottom where the air enters and passes through and escapes between the housing of the fixture and the glass plate. A view of these fixtures installed in one of the wards of the Post Graduate Hospital, New York, is shown in Fig. 7.

If it is so desired one lamp in a fixture may be arranged to operate on a separate switch, but this is not advisable on account of its effect on the patients. Night lights, wherever

Fig. 7.—Night view of typical ward in Post Graduate Hospital, New York, using dustless fixture shown in Figs. 3 and 3a.



Figs. 8 and 8a.—Adjustable ward bracket, lower figure showing correct method of installing.

Fig. 9.—Conical microscopic reflector.

necessary should be in the form of brackets and as inconspicuous and as far out of the range of vision as possible.

When a direct indirect system is to be used the character of the glassware used for the bowl or hemisphere must receive a thorough study; it should be of sufficient density to maintain the presently given intensities per square inch of exposed sources and have diffusion qualities which render it impossible to have any bright spots or streaks from the lamps exposed to the eyes of the patients. It is also advisable to eliminate the necessary gas emergency equipment from these fixtures, but it may be included in the localized equipment.

For the localized lighting of the ward the two forms most advisable are proper brackets or "bedside" lights; everything depends on the word "proper." No source of light or illuminated surface exceeding 0.05 candle-power per square inch (7.2 candle-power per square foot) should be exposed to a patient's eye; therefore, the usual direct lighting equipment is quite out of the question. An excellent form of bracket fixture is shown in Fig. 8. It is adjustable in every direction and it is equipped with a reversible glass reflector with opaque sides. The reflecting portion is of a concentrating type, designed especially for bedside examination, thus eliminating any necessity of the use of a special portable lamp by attending physicians; and by reversing directly upward this concentrated light is directed to the ceiling, thus giving an excellent form of indirect illumination.

The opaque sides render it impossible for a ray of light to reach the eye of a patient in any part of the ward and enable any bed to be immediately illuminated without any disturbance to other patients. An entire ward equipped with one of these brackets to each bed would not require any other form of illumination and the emergency gas equipment may be easily incorporated in this fixture. Many hospital equipment specialists and authorities predict this to be the future form of ward lighting.

"Bedside" lights are the least desirable for a localized equipment, but where absolutely necessary, they should be carefully designed. The reflector portion should preferably be hemispherical in form, opaque and mounted on a plain standard heavily weighted at the base. The reflector should be adjustable

by means of a knuckle joint. The reflecting surface should give a diffused reflection as from opal glass or flat white enamel. Of course an additional light is required for the physician for bedside examinations, thus making this equipment more costly in both initial expense and maintenance, as both equipments have to obtain the energy from base board receptacles which naturally necessitate a considerable portion of exposed cord, making the liability of breakage considerable and costly.

In the examination of bacteria under a powerful microscope, it is always difficult to arrive at definite results when observers at various points are working under light sources of varying spectral value. Varying light sources naturally produce a different tonal value to a germ so that it is often difficult, if not impossible, to be sure of identification.

Fig. 9 shows an instrument whereby there may be obtained at any time a uniform light source giving approximately the effect of a slightly veiled north light, which is so much desired in precision work, and far superior to the average illumination obtainable from city windows. The light from a 60-watt all frosted tungsten lamp operating at exact line voltage is directed by means of a double convex reflector with the lower surface of silvered glass and the upper surface of opal glass.

A carefully calibrated liquid lens is inserted at the aperture. After the light has passed through this lens the resultant illumination on the microscopical field is of a daylight spectral value. For dark field work this lens is changed to one giving an illumination of a powerful violet character.

Other lighting apparatus of the hospital has been intentionally not discussed in this paper because in the author's opinion it does not call for the study given the conditions herein mentioned.

The lighting of halls and corridors is in a class with the lighting of hotels and office building corridors. The nurses and doctors quarters should receive the same careful treatment required for the lighting of the home. The dispensary should be given the same treatment as the modern drug store; particular attention should be given to the lighting of the prescription counter.

DISCUSSION.

MR. H. CALVERT: This paper is a good article for a person to read who is about to design the lighting of a hospital. It is very practical. The lamp fixtures shown for the operating room certainly would give good results; but one reason why the authorities of some hospitals object to having the lamps placed directly over the operating table is the liability of dust or dirt falling from the fixture and infecting the patient. To obviate this, some hospitals have adopted the plan of installing four units approximately above the corners of the operating table.

Referring to ward lighting, indirect fixtures are quite suitable provided the amount of illumination which falls on the ceiling is not excessive, as the patients, a large part of the time, are lying on their backs and to gaze upwards at a very bright ceiling is of course uncomfortable. The adjustable ward bracket which is shown in the paper is a good one for the purpose. In one of the Philadelphia hospitals this bracket arrangement has had a unique feature added by equipping the bracket with a pull socket so that the patient can light the lamp, and at the same instant a little pilot lamp which is located near the desk of the head nurse is also lighted indicating, if she has not already observed it, that the patient desires attention.

MR. W. F. LITTLE: Referring to the lighting of operating tables, I note that Mr. Wheeler states that an intensity of 10-foot-candles has been found sufficient. Comparing this with illuminations given by the Zeiss* system, we find intensities in the neighborhood of 300-foot-candles, and I further understand that this system has been used with very good success in various hospitals. I should be interested in knowing whether Mr. Wheeler believes 10-foot-candles sufficient for operating table lighting in general.

Admittedly, the light of hospital wards should be done under the principle of the greatest good for the greatest number. Therefore, would it not be feasible to turn an indirect system of illumination upside down directing the light first upon the white floors and from there diffused throughout the room?

* Illumination measurements of Zeiss system given in I. E. S. TRANSACTIONS, June, 1912.

MR. H. B. WHEELER: *Operating Rooms.* The lighting of hospitals is a very important subject and one we know very little about. This is especially true in operating room illumination. It has been my experience that extreme concentration of light on the operating table, not only gives a multiplicity of shadows, but an intense heat, both the opposite to what is desired, namely, an evenly diffused light. Indirect Illumination from the ceiling and walls gives an abundance of diffusion eliminating completely objectionable sharp shadows.

Several large operating rooms of the Toronto General Hospital and St. Mary's Hospital at Rochester, Minn., have been lighted for some time with indirect illumination which is giving very satisfactory results for operating purposes. The indirect fixtures are very plain arm chandeliers with adapters for supporting one piece silvered glass reflectors. The average intensity is approximately 10-foot-candles.

Another system of diffuse illumination has been in use for the past six years in the Southern Pacific Hospital at Los Angeles, Cal. It consists of a battery of one piece silvered glass reflectors suspended over a chipped glass skylight. In installing a system of this character, care should be taken to select glass of good diffusing qualities.

Corridors. Corridor lighting is just as important as the lighting of any other room in a hospital, because patients are continually being taken from the wards and private rooms to the operating table at critical stages. For this reason the lighting should be concealed as in other parts of the institution.

Wards. It is very desirable in wards to have a flexible system of indirect illumination.

A low intensity (¼ foot-candle) for a night light, a medium intensity (½ to 2 foot-candles) for reading, etc., and a high intensity for close examination of patients are required. Localized direct lighting portables attached to baseboard outlets between beds are used largely for the high intensity.

Generally in large wards varying degrees of illumination are controlled by electrolier wall switches and the smaller wards by switches on the fixtures.

When luminous bowls are desired, the small lamp for illuminating the glass bowl may be used for a night light.

STORE LIGHTING.*

BY J. E. PHILBRICK.

Synopsis: The gaslighting installations of eight small stores are outlined in this paper. Plans showing the locations of test stations, and illumination readings of each store are also included. The author emphasizes two points: (1) gaslighting solicitors should have available for prospective customers accurate data on local lighting installations; (2) the need of proper maintenance to insure maximum efficiency and satisfaction.

The author hopes that the publication of the tests and data of this paper and a discussion of them may go far towards eliminating the old "hit or miss" methods used by commercial departments in securing business and also in making installations.

The following table gives average results† of tests of the lighting installations in several stores, plans of which are shown in the accompanying illustrations.

TABLE I.

Lighting unit	Nominal consumption of unit cu. ft.	Lumens per cu. ft. of gas per hour light ceiling — With light walls	With dark walls
Reflex lamps with frosted tip cylinders, prismatic or light (imported) opal concentrating reflectors.......	3⅓	125	114
Reflex lamps with frosted tip cylinders, prismatic or light (imported) opal distributing reflectors........	3⅓	110	100
Reflex lamps with frosted tip cylinders, French roughed ball globe...	3⅓	95	70
Reflex cluster lamp, four-mantle, with alabaster globe....................	13	85	64
Inverted five-mantle arc with alabaster globe	16.6	87	65
Upright four-mantle arc with opal reflector and alabaster globe........	20	75	55
Upright four-mantle arc with alabaster globe only.......................	20	66	48

* A paper read at the seventh annual convention of the Illuminating Engineering Society, Pittsburgh, Pa., September 22-26, 1913.

† Figures published by a manufacturer of lighting appliances for use in the design of gas lighting installations.

The installations tested were selected at random and under ordinary working conditions, no special preparation of lamps or mantles being made in any case. If renewals had been made they were made at the ordinary time for cleaning, and as the test shows there is but one case in which the units had received attention within one day of the time of making tests.

For some time the opinion has prevailed that figures relative to the performance of gas lighting units required radical discounting in order to express the actual results secured upon a consumer's premises, under the conditions of care and attention usually encountered in actual service.

Obviously, it is most important for the man responsible for the success of any business to obtain accurate information concerning the excellence of the service rendered by his product with particular reference to those features directly under the observation of the consumer, and upon which the latter bases his judgment of the service and product. Many gas companies have been deterred from gathering this data by the effort required to obtain it. I believe, however, that the value of this information is amply demonstrated in the tests reported in this paper which were made in York, Pa. Tests of this character not only enable the manager to determine the competitive position of his product and to keep a check on the capacity of his manufacturing distribution and maintenance departments as regards the performance of their various functions in supplying lighting service, but form a basis for calculation by salesmen in designing installations and advising customers.

When salesmen use data furnished by the manufacturer of lighting appliances, they are naturally inclined to make rather liberal discounts to allow for discrepancies between service and laboratory conditions, and for the pardonable optimism naturally to be expected on the part of the manufacturer.

The accompanying table published in the "Gas Solicitor's Handbook" was believed at the time of publication to be representative of the results that might be expected in actual service under good conditions with clean lamps and new mantles of good quality, and laboratory tests have indicated that the depreciation which results from burning over the reasonable period of time elapsing between maintenance calls should be negligible.

It was desired to substantiate this in practise, and I was very much gratified to find that this was done.

Lacking facilities for determining the gas consumption in each case 3⅓ cubic feet per hour was taken as presumably a close approximation to the actual consumption, the sizes of the mantles indicating that on gas of the quality furnished, this assumption was reasonably accurate.

Tests made upon new mantles of known efficiency confirmed this opinion.

In determining upon a procedure for these tests, horizontal illumination upon the working plane was selected as the basis. Not because this is the only plane requiring illumination but because with practically all the glassware usually sold for store illumination, a sufficient degree of horizontal illumination is always accompanied by at least a sufficiency of illumination upon other planes. The main purpose was to obtain information which might assist us in furnishing illumination to our customers under the most favorable conditions.

There are several matters that are worthy of some special attention in connection with these different installations. It will be noticed that in many cases the illumination was measured at comparatively few points, and while the numerical average of the results would not give the actual average obtained throughout the entire area, the numerical average is in all probability somewhat below the true average which would have been obtained had a greater number of readings been taken. For instance, in both Figs. 1 and 2, it will be seen that most of the measurements were taken in the more poorly illuminated portions of the room, very few being taken at points immediately beneath the lamps where the illumination would be the highest. This statement also applies to Figs. 3, 4 and 5. With regard to Fig. 7 the actual average illumination is probably far above the figures which we have given, possibly as much as 20 to 30 per cent., on account of the fact that the lamps were quite low and most of the readings were taken at situations so far from the lamps that they were outside of the range of effective distribution. In this particular instance, of course, the really important consideration is the amount of light on the face of the customer, and the lamps

are properly arranged to distribute the light for this purpose in the best manner, and the general illumination of the room is of much less importance.

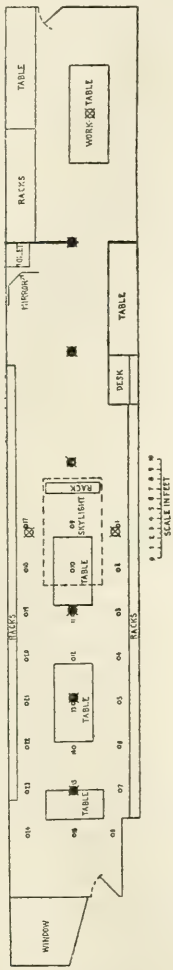


Fig. 1.—Plan of tailor shop.

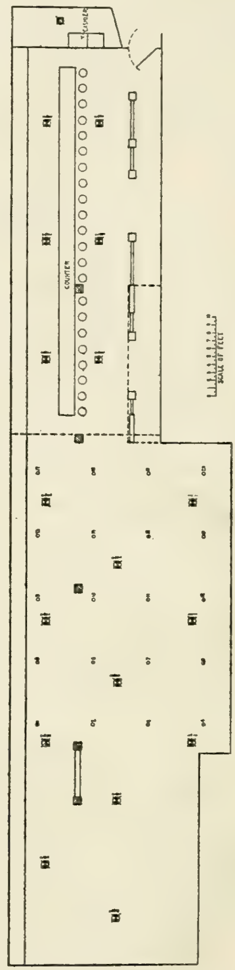


Fig. 2.—Plan of lunch room.

In the store shown in Figs. 7 and 8, it will be noticed that a greater number of readings were taken and these probably represent truer averages than any of the others.

An interesting point is that, according to the Gas Solicitor's Handbook, (page 30), is claimed that a cubic foot of gas per

hour will produce about 110 effective lumens in a room with light side walls (that is, a sufficient amount of light to illuminate

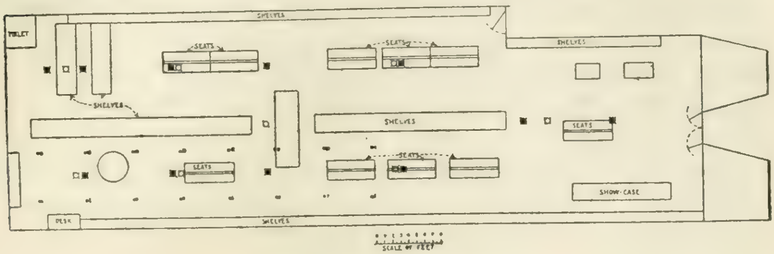


Fig. 3.—Plan of shoe store.

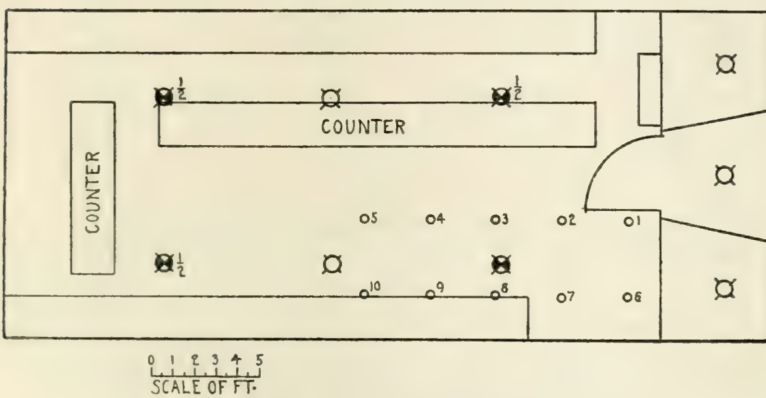


Fig. 4.—Plan of jewelry store.

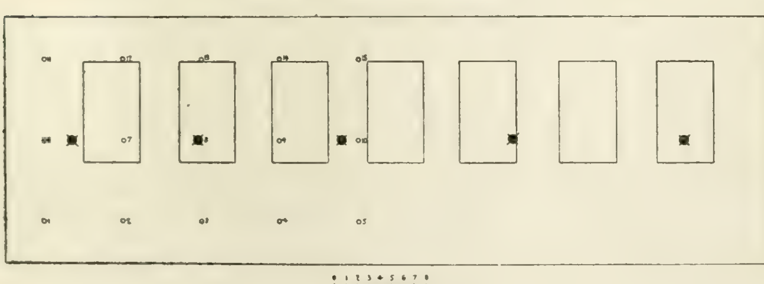


Fig. 5.—Plan of pool room.

110 square feet to an intensity of 1 foot-candle) and with dark walls 100 effective lumens. From the numerical averages, as obtained in the test, it will be noted in the last column that there

was only one gas installation which dropped a sufficient degree below the nominal efficiency stated in the handbook to make the matter worth considering, and this is the barber shop, in which as I stated above, the lamps were so low that most of the readings came outside of the effectively lighted area, so that as far as indicating the efficiency of the gas service and maintenance, this should be eliminated.

The installation shown in Fig. 1 had not been maintained for two months, and was only 1 per cent. below the nominal efficiency. Installation No. 2 was 3 per cent. below.

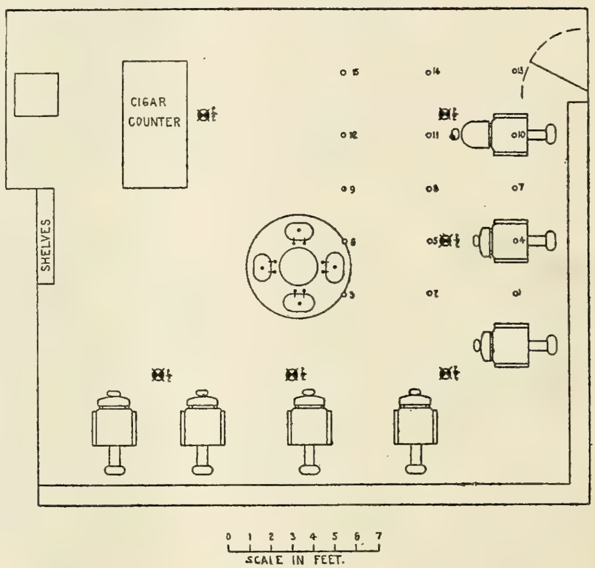


Fig. 6.—Plan of barber shop.

The value of tests of this character, both to the gas company and to the industry at large, is to my mind quite apparent and extends not only to the solicitation of new business, but to the proper design of lighting systems and to the maintenance of existing installations.

As regards the soliciting of new business, actual tests of installations of which the prospect has personal knowledge reinforces the arguments of the salesman most forcibly.

In many cases, contracts for lighting hinge mainly upon econo-

mic considerations. Every salesman claims the highest economy for the particular illuminant he happens to be selling. His claims are of necessity based upon laboratory tests, or upon service tests in other localities in which the conditions may or may not approach those in his own situation. He can submit no evidence of the validity of his claims that has much weight with the customer. In such cases tests upon installations in the same locality are very convincing, particularly if some of them happen to have been made upon the premises of the customer.

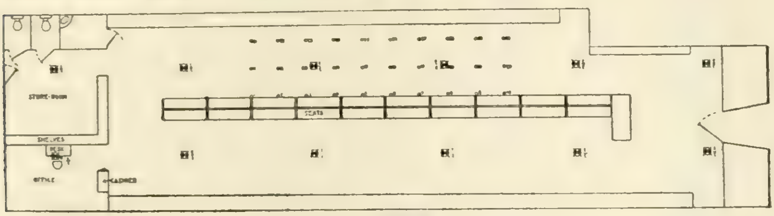


Fig. 7.—Plan of shoe store.

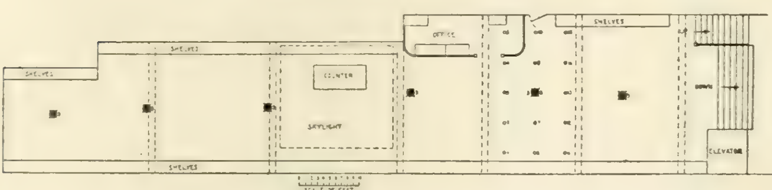


Fig. 8.—Plan of carpet and rug store.

In the case of the barber shop quoted above, the proprietor himself took simultaneous readings with the operator and saw for himself the true comparison between competitive illuminants so far as the amount of light he was getting was concerned, and even though the amount of light fell 43 per cent. below the theoretical, the illumination was nearly twice that which was given when the shop was lighted by the competitive illuminant.

A test like this gives the consumer an exact idea of the comparative value of competitive illuminants and makes a valuable reference for the solicitor of the gas company, inasmuch as the conditions are approximately the same under any city and the solicitor has but to refer to the test and the consumer personally for a confirmation of the data with which he is trying to secure the business of a prospective customer.

Photometric Data.

Fig. 1.

Station	Foot-candles
1	1.6
2	2.6
3	3.8
4	4.0
5	4.3
6	4.1
7	3.7
8	2.7
9	2.3
10	5.2
11	7.8
12	6.8
13	7.0
14	6.7
15	6.0
16	3.65
17	1.6
18	3.2
19	4.5
20	4.5
21	4.6
22	4.5
23	4.9
24	2.4

Fig. 2.

Station	Foot-candles
1	6.0
2	5.3
3	4.5
4	3.3
5	4.5
6	5.2
7	4.2
8	1.85
9	5.8
10	5.3
11	3.7
12	1.78
13	5.1
14	5.0
15	4.0
16	2.2
17	5.6
18	3.3
19	1.74
20	2.2

Fig. 3.

Station	Foot-candles
1	3.1
2	3.9
3	5.7
4	7.3
5	4.8
6	6.6
7	2.25
8	5.8
9	5.1
10	2.0
11	6.4
12	4.0
13	6.3
14	4.4
15	3.2
16	3.0

Fig. 4.

Station	Foot-candles
1	2.2
2	5.5
3	7.8
4	7.0
5	4.0
6	1.9
7	4.25
8	8.0
9	7.2
10	4.7

Fig. 5.

Station	Foot-candles
1	1.30
2	1.00
3	1.16
4	.80
5	.90
6	13.00
7	6.50
8	12.50
9	5.50
10	9.20
11	1.46
12	.86
13	1.77
14	1.13
15	1.70

Fig. 6.

Station	Foot-candles
1	3.6
2	6.2
3	3.5
4	2.5
5	5.6
6	3.0
7	4.0
8	7.3
9	1.5
10	4.7
11	7.0
12	2.8
13	3.3
14	4.4
15	1.45

Fig. 7.

Station	Foot-candles
1	2.20
2	3.00
3	4.50
4	5.00
5	3.60
6	2.60
7	4.30
8	5.15
9	4.25
10	3.00
11	2.30
12	3.60
13	6.08
14	5.26
15	3.54
16	3.20
17	4.45
18	5.40
19	4.20
20	3.10
21	2.70
22	3.00
23	3.65
24	3.75
25	2.90
26	2.20
27	3.55
28	4.10
29	3.55
30	2.40

Fig. 8.

Station	Foot-candles
1	1.34
2	2.09
3	2.74
4	2.40
5	1.15
6	1.34
7	1.96
8	3.09
9	3.05
10	1.52
11	1.70
12	3.03
13	3.53
14	3.47
15	1.47

Fig. No.	Business	Gas: Area sq. ft.	Ceiling height	Height of lights	Walls	No. of outlets
1	Tailor shop........	979	14′–0″	9′–	Medium	6
2	Lunch room.......	2,704	12′–8″	10′–6″	Medium	17
3	Shoe store.........	2,066	12′–0″	8′–6″	Light	11
4	Jewelry store	450	10′–6″	8′–6″	Dark	4
5	Pool room.........	1,487	9′–6″	7′–8″	Dark	5
6	Barber shop	611	8′–8″	7′–2″	Light	6
7	Shoe store.........	1,916	15′–0″	10′–0″	Light	10
8	Carpet store	2,318	18′–0″	11′–0″	Dark	6

Fig. No.	Business	Gas: Lamps per outlet	Type	Reflector
1	Tailor shop........	2	6 Reflex	Extensive prismatic
2	Lunch room.......	14-2L., 3-1L	"	" "
3	Shoe store.........	2-1L., 1-2L., 6-3L., 2-4L.	"	" "
4	Jewelry store	2	"	" "
5	Pool room.........	4	"	" "
6	Barber shop	2	"	" "
7	Shoe store.........	2	"	" "
8	Carpet store	3	"	" "

Fig. No.	Business	Gas: Total con. per hour	Illumination: Average	Minimum	Maximum
1	Tailor shop........	40.0 Cu. ft.	4.26	1.6	7.8
2	Lunch room	102.3 " "	4.2	1.74	6.0
3	Shoe store.........	99.0 " "	4.61	2.0	7.3
4	Jewelry store	26.4 " "	5.25	1.9	8.0
5	Pool room.........	66.0 " "	3.92	0.8	13.0
6	Barber shop	39.6 " "	4.06	1.45	7.3
7	Shoe store	66.0 " "	3.76	2.20	6.08
8	Carpet store	59.0 " "	2.25	1.15	3.53

Fig. No.	Business	Gas: Eff. Lm. per cu. ft. or watt: Actual	Theor.	Per cent. Actual below theor.	Time since maintained
1	Tailor shop........	104.0	105	0.1	2 Months
2	Lunch room	108.0	105	*3.0	1 Day
3	Shoe store.........	96.2	110	12.5	Not maintained
4	Jewelry store	90.0	100	10.0	1 Month
5	Pool room.........	88.3	100	12.0	1 Month
6	Barber shop	62.6	110	43.0	1 Week
7	Shoe store.........	109.5	110	0.5	1 Week
8	Carpet store.......	87.6	100	12.2	1 Month

* Increase

I believe that it would be of much value to the commercial departments of all the gas companies to have tests like the above made and printed and copies given to their solicitors, thus enabling them to meet the question of the consumer "How do you know" with data which applies to the question at hand and not an irrelevant mass of figures which mean nothing under the local conditions.

The great feature of help to solicitors is not that the consumer will understand terms of illumination intensity but that he can see for himself the real value of his lighting and the effect on his pocket-book in dollars and cents which to him is a thing of vital interest.

Heretofore the designs of installations have been made at random, the lighting effects have often been not satisfactory upon the first trial, a second and sometimes the third attempt being necessary to give the consumer the proper light in the proper place. This often entails considerable expense to the consumer and company and creates dissatisfaction.

It is a fact that the lighting engineer of the manufacturer has been at the disposal of the gas companies for sometime back, offering to lay out installations and perform all the illuminating engineering work, but how many of the companies have taken advantage of this offer. If solicitors would make a series of tests, and compute a table of lighting efficiency in various store-rooms they could easily prevent mistakes in future installations.

Manufacturers' hand-books are all right, but they are too often discounted or ignored, but data gotten right in the field under the local conditions cannot be discounted or ignored but are convincing facts.

There is one test which I did not have time to prepare but would have been advisable to undertake and that is a test on temperature at various points in our stores under the gas and electric lighting, taking into account the outside temperature difference on the different days of test. I believe the heat objection against gas lighting can be greatly diminished, if not eliminated.

Lastly, it is realized that the efforts of the illuminating engineer are entirely lost if the lamps are not kept clean and the mantles renewed at proper intervals. It is absolutely necessary to have

men who are careful and intelligent, who have some knowledge of the lamps they are cleaning; and who know when the adjustment of the lamp after cleaning is as near right as possible to get maximum efficiency. Too often do companies try to economize on this most important part of their business by employing boys at very small fixed wages, and expecting them to have the inclination to become illuminating experts. To my mind the only way to pay lamp maintainers is on the sliding scale plan with the deduction for complaints on lamps which they have maintained and caused the consumer trouble. The lamp, whether gas or electricity, must have clean glassware and bulbs for much business is lost by our failure to attend to these features. Of course, it costs more to maintain lamps properly than it does to clean them in a half-hearted manner, trying to keep the cost down at the expense of the illumination. This, however, can be met by a proper and not excessive charge based on the sliding scale of consumption per mantle. (It is obviously not fair that the large consumer of gas or other illuminants should pay at the same rate for his maintenance as the consumer who uses his lights merely as a makeshift.) Below is the maintenance schedule which is in use by a gas company in York, Pa., which was adopted after careful consideration by the officers of the company. This schedule is giving entire satisfaction to the consumer and company alike.

YORK GAS COMPANY

York, Pa., ...1913.

The undersigned at number ....Street, York, Pa., hereby makes application to the York Gas Company to use gas for illumination, at the regular rate of the Company.

It is further understood that this application, being approved, the York Gas Company agrees to loan and install the necessary Gas Lighting Fixtures, Piping, etc., free of cost.

In all cases where combination Gas and Electric Fixtures are specified and installed, the undersigned agrees to use Gas regularly on such fixtures from September 1st to May 1st, that said fixtures remain in his premises.

These fixtures will be given regular monthly inspection, new mantles supplied as needed, be cleaned and adjusted and be given such other additional attention as may be necessary to keep fixtures in good working order.

In consideration of the above the undersigned agrees to pay maintenance according to the following scale:

Consumption per mantle per month,	50 feet or less	15	cents per month
" " " " "	100 " " "	10	" " "
" " " " "	125 " " "	9½	" " "
" " " " "	150 " " "	9	" " "
" " " " "	175 " " "	8½	" " "
" " " " "	200 " " "	8	" " "
" " " " "	225 " " "	7½	" " "
" " " " "	250 " " "	7	" " "
" " " " "	275 " " "	6½	" " "
" " " " "	300 " " "	6	" " "
" " " " "	400 " " "	5½	" " "
" " " " "	500 " " "	5	" " "
" " " " "	600 " " "	4½	" " "
" " " " "	700 " " "	4	" " "
" " " " "	800 " " "	3½	" " "
" " " " "	1,000 " " "	3	" " "
" " " " "	1,250 " " "	2½	" " "
" " " " "	1,500 " " "	2	" " "
" " " " "	2,000 " " "	1	" " "

All maintenance to be paid monthly.

Orders taken by...................... Signed......................

Finally, gas men should appreciate the possibilities of gas lighting, determine exactly the intensity of light in store-rooms, factories, etc., approach consumers with more intelligible, convincing data, and keep the lamps clean and properly adjusted.

By doing this, it has been said, "Two units can be made to grow where only one grew before."

The writer wishes to acknowledge his indebtedness to Mr. R. F. Pierce, for his help in the preparation of this paper.

DISCUSSION.

MR. R. F. PIERCE: Inasmuch as these statistics were taken for a purely commercial purpose and intended to set forth only the existing lighting service conditions in actual installations, no deductions into which enter such considerations of gas pressure or electric voltage should be drawn. While these data were taken, they were not presented in the paper which is simply a statement of lighting conditions in a certain locality under the conditions found, and having no reference whatever to any other set of conditions.

I think Mr. Philbrick rather over-estimates the amount of assistance that he received from me. I furnished the illumination measurements, and in that connection should like to explain the

method used. The measurements were comparatively few, the idea being to obtain some sort of an average figure which should at least be low. It was impossible to devote the time necessary to take a larger number of measurements which would have given more accurate figures, but the results were comparative rather than absolute. Mr. Philbrick wished particularly to obtain an idea concerning his position in the competitive field and to ascertain how closely the published figures for effective lumens per cubic foot were approached in his situation.

In this connection, I would emphasize that the table given on the first page of the paper does not refer to measurements obtained at York, but to figures for effective lumens per cubic foot published by a manufacturer of gas lighting appliances for use in the design of installations. These figures represent averages of a number of practical installations and have been given out as a practical basis for the design of gas lighting systems.

In the tests at York a number of installations were selected in which combination fixtures were used with the same type of reflector on both gas and electric outlets and measurements were made on both systems at the same points to show a comparison between the two. The gas company had no prior knowledge either of the date of the test or the installations that would be tested. The latter were picked out at random without reference to the condition of the lamps or of the installation. The tests on the gas lighting installation showed a maximum discrepancy between the data published by the manufacturer and the results obtained under these tests of about 12.5 per cent., with the single exception of one installation in which the number of test stations was so small that, on account of the very low height of the lamps, the majority of the test stations fell outside of the effective radius of the lamps. In this installation the discrepancy between published figures and the average obtained was 43 per cent. That this discrepancy was due to the location of the stations is indicated by the fact that a test of the electrical installation at the same points showed a discrepancy of 60 per cent. from the commonly used data for effective lumens per watt, so that in both cases the discrepancy appears to be due to the condition mentioned. I do not mean to convey the impression that the relative service conditions found in this situation exists in the

majority of plants. As I remember the figures, the average discrepancy for effective lumens per watt obtained in the electrical installations was in the neighborhood of 40 to 45 per cent. It is quite obvious that this was due to a large extent to failure to replace the lamps at proper intervals and to select lamps of proper voltage. A comparison between the two services emphasizes the advisability of central stations and gas companies obtaining actual illumination measurements in order to determine the lighting service really given to their customers under the conditions of actual use. The electric service in this particular situation was plainly below the average, while the gas lighting service was much better. There are, of course, many cases in which this comparison would be reversed. The results of this test emphasize the fact that no general comparison between the service rendered by the two illuminants is possible. The most important factor is the quality of service rendered in each particular situation.

MR. T. J. LITLE, JR.: It is very agreeable to note in Mr. Philbrick's paper that the data that he has obtained at York compares very favorably with the published data on the same types of lamps which he tested. It is a fact that published data on many of these lamps is in many cases conservative from the fact that the tests were made under 2.5 inches water pressure, while in many cities the service pressure is much higher than this, and they consequently get increased candle-power and efficiency from their burners.

For instance, the consumer's service pressure in Chicago is 6 inches while in San Francisco it runs considerably higher than this. It may be interesting for you to know that considerably higher efficiencies than those which have already been published are expected in the near future. They have already been reached experimentally. For instance, it is quite possible with certain sizes of inverted lamps to exceed 30 candles per cubic foot, mean lower hemispherical rating. In fact, I have seen as high as 53 candles per cubic foot, mean lower hemispherical rating, the lamp burning on low pressure (2½ inches water pressure).

It is a remarkable fact when looking back over the development of gas and electric lighting systems that in the year 1880 the

most radical developments took place, namely, the Edison incandescent electric lamp and the Welsbach incandescent gas lamp. Ever since that date, whenever there was a radical development in the one system, there was something brought out in the other to meet it.

Mr. Ward Harrison: Mr. Philbrick's paper is very interesting to me. It shows what an effective weapon poor service on the part of one lighting company may afford its competitor. It has been found, however, that comparative, tests of this character too frequently lead to bad feeling between the lighting companies interested. This feeling can be changed to one of good natured rivalry simply by making it a practise in each case to notify everyone interested in the test and arranging for them to attend. It has been found, also, that when the prospective purchaser and the representatives of all the competing interests are present at the time of the tests, much of the dissatisfaction in regard to test methods and results which so often follows, is obviated.

Mr. E. B. Rowe: I cannot emphasize too strongly Mr. Harrison's contention that operating companies should know what results the customers are getting from service on their lines. The making of installation tests similar to those covered in Mr. Philbrick's paper is certainly to be commended, but the conditions under which test is made should be clearly recognized. In making use of such test results complete data should be given or the results should be reduced to a common equivalent basis.

For instance, on the third page no reference is made to a measurement of the gas pressure, which of course is one of the variables in the test and has a considerable influence on the results obtained. In the same way in tests on an installation of electric lamps the exact voltage on which lamps were operated during the test should be stated and the effect of voltage variations made clear to the layman or the results could be reduced to the normal voltage or gas pressure. Personally I have some hesitancy in making use of published data unless all the facts are at hand and I believe care should be taken in presenting test results to cover all questions which are likely to arise in the minds of those who may wish to use the data.

DISTINCTIVE STORE LIGHTING.*

BY CLARENCE L. LAW AND A. L. POWELL.

Synopsis: Certain stores, namely the high-class shops, demand a striking individuality of design. This paper describes in detail several typical lighting installations which have come to the attention of the authors; it discusses a particular store of each of several classes: shoe, millinery, toy, candy stores, etc. Data are given as to the dimensions, wall, ceiling and floor coverings, arrangement of fittings, type of glassware, number and sizes of lamps, and a general description of the appearance of each store. This information may not be directly applicable to the design of a new installation, but since the lighting systems outlined are giving satisfactory service, the quantitative element may be of use and the novelty of some of the equipments may suggest to the designing engineer ideas which will be applicable to his particular problem.

If one pauses to analyze retail places of business as a whole, it becomes evident that a convenient and complete classification may be made as follows: ordinary small stores, large dry goods and department stores, and high grade shops.

The authors treated the first of these classes in a paper presented at the last convention[1] of the Society; they realized that high efficiency of light utilization, low initial cost of installation, low maintenance and simplicity were the determining factors. It seemed desirable to suggest a standard practise, and an attempt was made to do this on the basis of averages obtained from an investigation of a large number of stores of this class. Some criticism was elicited to the effect that this scheme would produce a monotonous condition, but the fact still remains that artistic appearance cannot be had cheaply, and, due to the small profit earned by a store of this sort, the amount spent for lighting is, of necessity, small.

In the large store, efficiency and artistic appearance become more nearly balanced. Artistic lighting implies good diffusion; and with the present commercial illuminants, this cannot be had

* A paper read at the seventh annual convention of the Illuminating Engineering Society, Pittsburgh, Pa., September 22-26, 1913.

[1] TRANSACTIONS of the I. E. S., Vol. VII, p. ——.

without some absorption of light. The merchant can afford to spend a relatively larger sum for lighting than could be spent by the small storekeeper, and some sacrifice of light is made to obtain better diffusion. The store should have a harmonious system of lighting for the main parts of the entire building, yet there are some parts which are, in reality, shops, and should be so treated. The general requirements for department store lighting have been discussed several times in the TRANSACTIONS* of the Society, and there is no need for their repetition in this paper.

A high grade shop should be considered quite differently from the monotonous store which is so common in large cities. Unlike a small store, it should be considered individually and with respect to its particular line of business. This shop is, as a rule, small, handsomely and lavishly furnished, splendidly finished to the minutest detail, and located in the most fashionable section; it handles only the best grade of goods (frequently imported) and sells to a discriminating class of customers. The proprietor or manager is willing to spend large sums for the right equipment and maintenance. The profits for each individual piece of merchandise sold are undoubtedly greater than in other stores, and therefore, more money can be spent for individuality of equipment. Artistic appearance is the predominant factor, and, therefore, a distinctive system of lighting is necessary, efficiency of the installation being a secondary consideration.

It should be the aim and desire of shopkeepers of this class to interest and attract prospective customers, making them permanent habitues of their stores. Some definite architectural scheme should be carried out or symbolism expressed. Many stores show the influence of the personality of the proprietor, and often such details as the dress of the sales force are in harmony with a certain predetermined plan.

Among the points which should be given consideration by a shop proprietor in planning a distinctive store, may be mentioned the following:

Design of the exterior; woodwork of the interior; color of

* C. L. Law and A. J. Marshall, "The Lighting of a Large Store," Vol. VI (1911), p. 186; H. W. Shalling.—"Department Store Lighting," Vol. VIII (1913), p. 17.

walls and ceiling; finish of show cases; floor covering; finish and type of lighting fixtures, glassware and lamps.

Numerous examples of distinctive store lighting have undoubtedly come to the attention of every one, but a description of a few which the authors have observed may indirectly suggest schemes which will prove of benefit and aid in the advancement of the art of lighting. In last year's paper, the quantitative element in designing the lighting was discussed. A number of stores were grouped under one heading, but with the case in hand where individuality of stores of any one type is the essential, it is necessary to use the "case" system, illustrating by example.

TOY STORE.

An effective lighting system of a toy store may be seen in F. A. O. Schwartz's store on Fifth Avenue, New York City. (Fig. 1). The building is of modern construction with a high ceiling supported by pillars. The entire interior, including walls, ceiling and show cases, is finished in white, affording an excellent background for the varicolored toys on exhibition. The store was formerly lighted by Nernst lamps with massive ornamental housings finished in gilt. These were of Renaissance design, and in keeping with the capitals of the columns in the main room. The heart-shaped Nernst globe was replaced by a 14 in. (35.56 cm.) opalescent glass acorn type diffuser, and 400-watt clear tungsten lamps were used. Diffusion is good and shadows from pillars and overhanging shelves are minimized.

Store

Length 145 ft. (44.20 m.).
Width 41 ft. (12.50 m.).
Approximate area 6,000 square feet (557.42 sq. m.).
Ceiling height 17 ft. (5.18 m.).
Lamps 12 ft. (3.66 m.) from floor.
15 400-watt, 4 250-watt clear tungsten lamps.
Total wattage 7,000.
Watts per sq. ft. (0.30 sq. m.) 1.2.

Window

60-watt bowl frosted tungsten lamps set in recessed mirrored pockets at front edge of window, spaced about 3 ft. (0.914 m.).

JEWELRY STORE.

Richness and splendor are symbolized by jewels and, therefore, the shop dealing in these, should be magnificently finished. The

store of E. M. Gattle, on Fifth Avenue, New York, Fig. 2 can well be used as an illustration. All of the show cases and furniture are of mahogany; immense gray marble columns and pilasters with gold capitals support a paneled ceiling, which is also of mahogany finish. The parts of the side walls not occupied by window space are a green tint, decorated in gold. The floor is of oak in parquet style. Light is furnished by eighteen shower fixtures, verde finish, using 40-watt all frosted round bulb tungsten-filament lamps, and in the paneled recesses in the front part of the store are eight cut glass hemispheres, accommodating two 25-watt clear tungsten lamps each. A high wattage is necessary with this system in a room of this style, as the reflection coefficients of the ceiling and walls are very low.

Store

Length 78 ft. (23.77 m.).
Width 38 ft. (11.58 m.).
Area 2,960 sq. ft. (274.99 sq. m.).
Ceiling height 13 ft. (3.96 m.).
Lamps 10 ft. (3.04 m.) from floor.
220 40-watt round bulb all frosted 16 25-watt clear tungsten lamps.
Total watts 9,200.
Watts per square foot 3.1.

Window

2 aluminum finish trough reflectors.
25-watt tungsten lamps spaced about 10 in. (25.4 cm.).
Backing of window green plush.

TOGGERY OR HABERDASHERY SHOP.

As this class of store caters entirely to men, the store fittings should not be radical to any appreciable extent. Neatness, simplicity, and up-to-date appearance should characterize the shop. The lighting system must be quite efficient, as a high intensity of illumination is desirable.

Fig. 3 shows a night view of the installation of one of the shops of Weber & Heilbroner on Broadway, New York City, which conforms excellently with the above requirements. Six-arm brush brass fixtures of well balanced proportions are used with clear 100-watt tungsten lamps and opalescent bowl shaped reflectors. Show cases, counters and woodwork are of polished mahogany; ceiling smooth white plaster; walls above shelves covered with green burlap, and floor of hard wood. The window trim is of circassian walnut, forming an excellent contrast to the

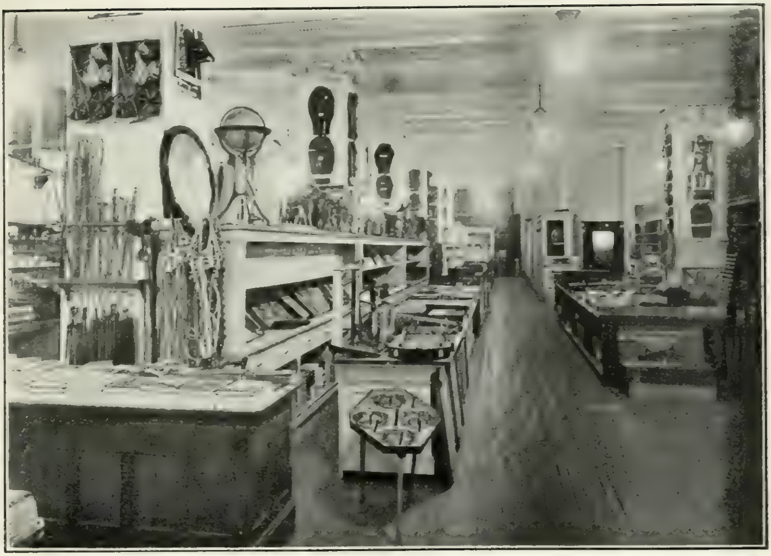


Fig. 1.—Distinctive illumination of a toy store.

Fig. 2.—Distinctive illumination of a jewelry store.

Fig. 3.—Distinctive illumination of a haberdasher's store.

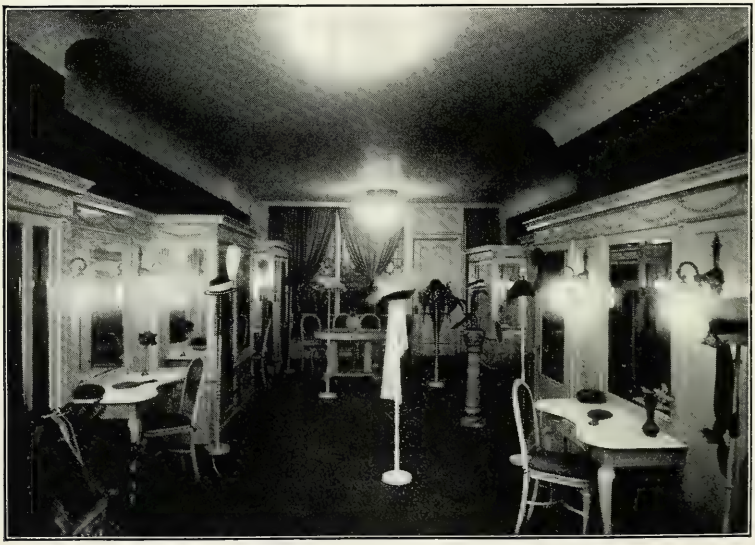


Fig. 4.—Distinctive illumination of a millinery store.

dark blue velvet backing for the goods on display. A white fixed shade, extending to within six feet (1.83 m.) of the sidewalk level, serves as a valance.

Store

Length 69 ft. (21.03 m.).
Width 18 ft. (5.49 m.).
Area 1,342 sq. ft. (124.77 sq. m.).
Ceiling height 13 ft. (3.96 m.).
Lamps 10 ft. 6 in. (3.20 m.) from floor.
30 100-watt clear tungsten lamps.
Total watts 3,000.
Watts per square foot 2.4.

Window

100-watt clear tungsten lamps.
Concentrating prismatic reflector.
Spaced 14 in. in a row along center of false ceiling.

MILLINERY.

Since Paris is the seat of fashions, to create the proper atmosphere, the display room should be "Frenchy" in character. Mme. Bruck's shop on West Fortieth Street, New York City, shown in Fig. 4 may be taken as an example. White show cases, covered with mirrors line the walls, and the dainty furniture is all finished in white enamel. White has the advantage that it does not "clash" with the colored materials of the hats and tend to divert the attention from the goods on display. The ceiling is of smooth, white plaster and a border of satin finish wall paper matches the old rose Wilton carpet and silk window hangings. Two ten-light brass finish shower fixtures with bowl-frosted tungsten lamps surrounded with crystal beaded glass, furnish general illumination. Localized illumination at the mirrors is supplied by side wall brackets, brush brass finish, Empire style, equipped with bowl-frosted tungsten lamps, shielded by crystal and old rose beaded shades. A few plants add to the attractiveness of the room.

Store

Length 40 ft. (12.19 m.).
Width 12 ft. (3.66 m.).
Area 480 sq. ft. (44.59 sq. m.).
Ceiling height 10 ft. (3.04 m.).
Lamps 9 ft. (2.74 m.) from floor.
Total watts 750.
30 25-watt bowl frosted tungsten lamps.
Watts per square foot 1.5.

Window

25-watt clear tungsten lamps in concentrating prismatic reflectors on 2 ft. centers.
3 25-watt tungsten lamps in crystal fixtures in center of window.
2 side wall brackets, cut glass shade and 25-watt tungsten lamps.

CANDY STORES.

One of the newest and most attractive of New York's Fifth Avenue stores is that of Schrafft, a view of which is shown in Fig. 5. A combination of semi-indirect and totally indirect illumination is used. The front portion of the store serves as a shop and is lighted by five three-light carved alabaster bowls suspended from the ceiling by silk-covered supports, and four one-light bowls, two on brackets and two on short pillars. The ceiling here is tan decorated with raised gold figuring; walls are elaborately decorated, with red, green and blue on a neutral backing. Show cases are of circassian walnut; pillars and floor of marble. A number of small decorative standards are used to illuminate the counters. The rear half of the store is used as a lunch room. In the center of this room is what is apparently a fern-covered urn. This contains a white enamelled reflector and a cluster of clear lamps, the light from which is directed to the cream colored ceiling and walls, lighting the room indirectly.

Store

Length 74 ft. (22.55 m.).
Width (average) 17 ft. (5.18 m.).
Area 1,200 sq. ft. (111.48 sq. m.).
Ceiling height 14 ft. (4.27 m.).
Lamps 10 ft. (3.05 m.).
5 150-watt clear tungsten lamps.
4 40-watt clear tungsten lamps.
15 60-watt clear tungsten lamps.
Total watts 1,810.
Watts per sq. ft. 1.5.

Window

Finished in circassian walnut; roof recessed with mirrored pyramidal reflectors and 25-watt clear tungsten lamps installed in squares on 18 in. centers.

Delicious sweets of great variety originate in the Far East, and an Oriental scheme of decoration for a candy store is, therefore, often appropriate. Fig. 6 shows a night view of the exterior of Page & Shaw's Fifth Avenue Shop. It can be seen that the window is partially covered with a delicate tracery of red, green and blue leaded glass; at night this is accentuated by illumination from lamps in the ceiling of the window. Three metal and art glass hanging fixtures are also part of the window equipment.

Free use of the primary colors is made in the decorating of the walls and ceilings of the store with conventional Moorish figures. The floor is of composition, red and white mosaic. It can be safely said that no two of the interior lighting units are alike: Oriental metal and colored glass domes, pottery vases lighted

from within and silk-covered lanterns furnish a very low intensity of general illumination, with a higher value on the counters and show cases.

The cashier's desk is surrounded by leaded glass made in the form of a miniature Turkish house, the whole surface of which is illuminated by a number of line source tubular tungsten-filament lamps concealed in its interior.

Store	Window
Length 30 ft. (9.14 m.). Average width 15 ft. (4.57 m.). Area 450 sq. ft. (42.8 sq. m.). Ceiling height 10 ft. (3.05 m.). Lamps 5 to 7 ft. (1.52 to 2.13 m.) from floor. Total watts 900. Watts per square foot 2.0.	Roof recessed with mirrored pyramidal reflectors; one ft. centers; clear 16 c-p. round bulb carbon lamps; 2 60-watt all frosted round bulb and 3 25-watt regular tungsten lamps in hanging lanterns.

GROCERY STORE.

A neat, attractive display will cause trade to flock to the store which is properly arranged. Cleanliness is a very important point to remember. There is no demand for a system of decoration for this class of store, but the walls, pillars and ceiling should have frequent painting. A dark wainscoting, the color of the shelves and show cases, with neutral walls and ceiling, makes an attractive combination. Almost any lighting unit which is neat and inconspicuous will serve.

D. M. Welch & Son's store in New Haven, Conn., shown in Fig. 7 serves as an illustration of the above requirements. The counters and show cases are of hard wood, natural finish; the trim is dark green; and the ceiling and walls are painted a light tint. Neatness is particularly characteristic. Two hundred and fifty watt tungsten lamps, in totally enclosing prismatic reflectors are used for general illumination. The unit is efficient and a satin finished lower half provides excellent diffusion. A short brush brass chain with canopy serves as the fixture.

Store	Window
Length 70 ft. (21.33 m.). Width 40 ft. (12.19 m.). Area 2,800 sq. ft. (232.25 sq. m.). Ceiling height 14 ft. (4.27 m.). Lamps 11 ft. (3.25 m.) from floor. 10 250-watt tungsten lamps. Total watts 2,500. Watts per square foot 0.9.	100-watt clear tungsten lamps in concentrating prismatic reflectors spaced 2 ft. 6 in. (0.76 m.).

TEA ROOM.

Coziness is the keynote of success of these establishments. A number of years ago a young woman started in a small way to sell home-made candy and pastry among her friends. Her energies soon developed into a methodical business system, and her products sprang rapidly into favor, with the result that "Mary Elizabeth" has branch shops in many of the large cities. Her New York store, which is shown in Fig. 8 and located on Fifth Avenue, is finished in white on the outside, with her facsimile signature in black serving as a sign.

The shop itself is modelled after a New England interior of fifty years ago; the ceiling is low and finished in white plaster; the floor of wide boards is painted a dark yellow and covered here and there with rag carpet "runners". The tea room proper is in the rear. On the right is an old fashioned fire place, and on the left a number of "stalls" similar to those found in taverns of bygone days. Small tables, covered with spotless linen, and gilt chairs are arranged as shown in the illustration. Shelves, counters and windows are trimmed with dainty white material.

Light is furnished by tungsten lamps in shirred silk shades which have a slight touch of color. Sixteen of these are attached to ceiling outlets and eight are on wall brackets.

The atmosphere of the room is extremely inviting and the scheme of decoration well executed.

Store

Length 62 ft. (18.90 m.).
Width (average) 18 ft. (5.49 m.).
Area 1,110 sq. ft. (103.11 sq. m.).
Ceiling height 8 ft. (2.44 m.).
Lamps 7 ft. (2.13 m.) from floor.

24 40-watt clear tungsten lamps.
Total watts 960.
Watts per square foot 0.9.

Window

40-watt tungsten lamps in shades as used in the store; row in the center of ceiling; 2 ft. (0.61 m.) centers.

SHOE STORE.

Most stores of this class have a center bench arrangement, the entire wall space being covered with boxes on shelves. A room of medium width will require at least two rows of units to give satisfactory illumination on the labels on the boxes and at the foot rests where the shoes are fitted and inspected.

A particularly novel layout is shown in Fig. 9, a night view

Fig. 5.—Distinctive illumination of a candy store.

Fig. 6.—Distinctive illumination of a candy store window.

Fig. 7.—Distinctive illumination of a grocery store.

Fig. 8.—Distinctive illumination of a tea room.

of Frank Brothers' Fifth Avenue (New York) shop. Entering from the street, one passes into the rotunda (shown in the background of the photograph) about 16 feet in diameter, the dome of which is supported by Corinthian columns. The floor is of mosaic marble and the ceilings, cream colored, with raised plaster decorations. Show cases, with attractive dressings, are grouped about the room. Suspended from the center of the dome is an ornamental inverted fixture containing eighteen lamps. This consists of six diffusing glass globes, pressed into the form of huge shells; below these are four round bulb carbon lamps enclosed in amber beaded glass.

The store proper is rectangular in shape and a balcony 6 feet (1.83 in.) wide extends completely around the interior. The cream colored ceiling beneath the balcony is divided by beams into squares. In the center of each square is a lighting fixture consisting of five pieces of pearl-like glass in the form of a large shell; a 40-watt clear tungsten lamp is located above each shell. At the base of the shell is a 25-watt round bulb all frosted tungsten lamp.

On each pillar from the balcony to the ceiling are located two two-arm brass brackets with clear gem lamps in roughed glass spheres. These serve to light the balcony and the center portion of the store proper.

The oak parquet floor is partly covered with rugs: the furniture is leather covered and the showcases and shelves are of mahogany.

Store

Length 64 ft. (19.5 m.).
Width 24 ft. (7.31 m.).
Area (main floor) 1,540 sq. ft. (143.07 sq. m.).
Height under balcony 8 ft. 2.44 m.).
Height above balcony 10 ft. (3.05 m.).
17 25-watt round bulb tungsten lamps.
85 40-watt clear tungsten lamps.
64 50-watt clear Gem lamps.
Total watts 7,000.

The value of watts per square foot would be of little signicance, as two types of lamps are in use, and also both the balcony and main floor are lighted.

Windows

Mirrored trough reflector with 50-watt Gem lamps outlets on 9 in. centers.

ANTIQUE AND CURIO SHOP.

In many cases the lighting requirements of an antique store are similar to those for a high class furniture store, that is, a low intensity of diffused light suffices. Exposed light sources are very objectional, as the polished surfaces show the reflection and glare is to be deplored in viewing the rare pieces on exhibition. Quite often the lighting units themselves are "objects d'art." Such is the case in the shop of Lewis & Simmons, shown in Fig. 10, where hand carved alabaster bowls with clusters of clear lamps furnish semi-indirect illumination.

The white ceiling, walls covered with dark red velvet and tan velvet carpet, make a good color combination for displaying the goods by contrast.

Store

Length 48 ft. (14.63 m.).
Width (average) 13 ft. (3.96 m).
Area 630 sq. ft. (58.57 sq. m.).
Ceiling height 14 ft. (4.27 m.).
Lamps 8 ft. (2.44 m.) from floor.
20 40-watt clear tungsten lamps.
Total watts 800.
Watts per square foot 1.3.

Window

Mirrored trough reflector with 25-watt clear tungsten lamps spaced 8 in. (0.20 m.) apart along the top of windows, and upright at the two sides to a height of about 4 ft. (1.22 m.).

BOOK STORE.

Scribners' new store, Fifth Avenue, New York, is an excellent demonstration of a carefully planned and well-executed scheme of lighting. The illustration, Fig. 11, shows very well the general appearance of the room. The ceiling of the main bay is vaulted and is of light gray sandstone with white plaster panels. This is lighted by means of line source tungsten lamps (approximately 25 watts per foot) the reflectors being located above the moulding running around the cove. Fourteen opalescent glass bowls, equipped with clusters of three lamps each, hung from the ceiling by long brass rods, furnish a feature which seems desirable, *viz.*, a visible source of illumination. The book racks and balconies in the side bays are lighted by 60-watt clear tungsten lamps in opalescent bowl-shaped reflectors. Paintings on the rear wall are lighted by individual mirrored trough reflectors equipped with 25-watt clear tungsten lamps on one foot centers. The entire

Fig. 9.—Distinctive illumination of a shoe store.

Fig. 10.—Distinctive illumination of an antique store.

Fig. 11.—Distinctive illumination of a book store.

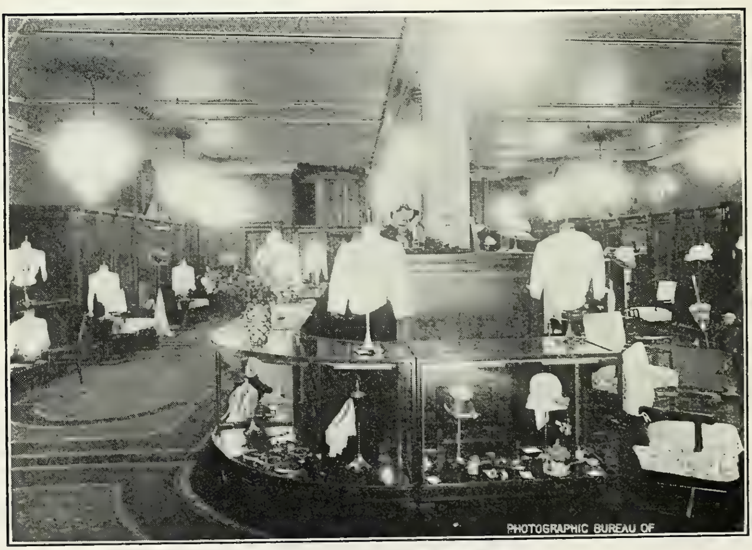


Fig. 12.—Distinctive illumination of a ladies' wear store.

front of the store is of plate glass, thus furnishing an excellent supply of daylight, and the cases and shelves being of light oak give the room a most cheerful appearance.

Store (main bay)

Length 98 ft. (29.87 m.).
Width 28 ft. (8.53 m.).
Area 2,740 sq. ft. (254.5 sq. m.).
Ceiling height (maximum) 30 ft. (9.14 m.).
Lamps 9 ft. (2.74 m.) from floor.
128 35-watt tubular tungsten lamps.
42 40-watt clear tungsten lamps.
Total watts (approx.) 7,580.
Watts per square foot 2.8.

Windows

No special lighting, as the windows extend to the top of the arch and the whole store is a flood of light.

LADIES' WEAR.

This type of shop is really divisible into two classes: namely, general and specialized.

As an example of the first class, the Fifth Avenue (New York) store of J. M. Gidding, which is shown in Fig. 12, may be given a little attention. The lighting units are of the sunburst" type, consisting of 6 regular and 6 round bulb, all-frosted tungsten lamps below a gilded composition plate, all suspended by a single chain. The fixtures are pleasingly harmonious with the cream colored ceiling and delicate gold lining. Show cases and woodwork are of magnificent circassian walnut, which blends well with the rich carpet of green and tan. The wall visible above the dressing room is largely covered with gilt figures.

Store

Length 55 ft. (16.76 m.).
Width 48 ft. (14.63 m.).
Area 2,640 sq. ft. (245.25 sq. m.).
Ceiling height 12 ft. (3.66 m.).
Lamps 9 ft. (9.74 m.) from floor.
90 20-watt all-frosted tungsten lamps.
90 25-watt all-frosted tungsten lamps.
Total watts 4,050.
Watts per square foot 1.5.

Window

Mirrored trough reflector with 25-watt tungsten lamps on 9 in. centers. White false ceiling, with two alabaster carved bowls, equipped with 6 40-watt tungsten lamps each, are suspended from this. Base and trim of window circassian walnut.

The specialized ladies' wear shop is exemplified by the shop of W. B. Crocker, Fig. 13, which handles mourning goods exclusively. The scheme of decoration is very appropriate. As one observer remarked, "A sombre cheerfulness fills the room." A rich gray carpet is but a shade darker than the wall covering, which, in turn, matches the woodwork of the show cases and trim. The chairs are of gray oak and tables of wicker work. The ceiling is white, and suspended from this by long chains are four seven-light and one fourteen-light shower fixtures, dull silver finished. Low wattage, bowl-frosted tungsten lamps are used with diffusing shades.

Under the balcony at the rear of the store are full-length mirrors. Localized illumination is provided at each by a 25-watt all-frosted round bulb tungsten lamp. In the front portion of the store, the general illumination is supplemented by two-arm brackets similar in finish and equipment to the overhead units.

Store

Length 76 ft. (23.16 m.).
Width 16 ft. (4.88 m.).
Area 1,210 sq. ft. (112.4 sq. m.).
Ceiling height 18 ft. (5.48 m.).
Lamps 10 ft. (3.05 m.) from floor.
60 15-watt bowl-frosted tungsten lamps.
18 25-watt round bulb tungsten lamps.
Total watts 1,390.
Watts per square foot 1.15.

Window

Mirrored trough reflectors equipped with 50-watt Gem lamps on 9 in. centers. Woodwork gray. Mirrors at side. Beaded crystal hemisphere set in center of the ceiling.

STATIONERY.

When mention is made of this class of store, one involuntarily pictures in his mind a low-ceilinged, dingy room with everything arranged in a haphazard manner; cigars, newspapers, candy and stationery in a grand mix-up. In contrast to this, is is pleasing to note Dennison's new store on Fifth Avenue (New York), Fig. 14. Immense square columns support a pure white ceiling beautifully decorated with raised plaster figures. The woodwork of shelves, drawers, show-cases and counters is of carefully selected weathered oak. Neatness is the predominating feature, and the semi-indirect lighting units of canary and white glass harmonize

Fig. 13.—Distinctive illumination of a ladies' wear store.

Fig. 14.—Distinctive illumination of a stationery store.

Fig. 15.—Distinctive illumination of a restaurant.

Fig. 16.—Distinctive illumination of delicacy store.

perfectly with this characteristic. The single-chain suspension and the bowl itself are designed along lines of simplicity. Six lamps are installed in each fixture.

A balcony is seen at the rear of the store; this is used for office purposes and is lighted by four four-light units with short ceiling suspension similar in design to the large units.

The space below the balcony has been given quite a bower-like appearance by the use of a false ceiling of green lattice work and a profusion of paper flowers.

Store

Length 67 ft. (20.42 m.).
Width 36 ft. (10.97 m.).
Total area 2,410 sq. ft. (223.88 sq. m.).
Ceiling height 18 ft. (5.48 m.).
Lamps 12 ft. (3.66 m.) from floor.
60 100-watt clear tungsten lamps.
Total watts 6,000.
Watts per square foot 2.5.

Window

Mirrored trough reflector equipped with tungsten lamps 25 watts per foot.

RESTAURANT.

There seems to be no definite practise with regard to the lighting or rooms of this nature. Some proprietors desire a great flood of light and the attendant sparkle as produced by crystal chandeliers; others demand a soft, well-diffused, low general illumination supplemented by localized table lamps. Bergfield's restaurant, on Broadway, New York, Fig. 15, is an example of lighting with the latter idea of proper lighting. Totally indirect single unit, mirrored reflector lighting units of composition moulded into an Egyptian design are used. Mirrors are set into the wall panels, and above each is a two-arm verde finished bracket with low-wattage multiple lamps and silk shades. The wood work is cream, with gold decorations; ceiling white; wall panels old rose, satin finish; chairs mahogany finish, and the carpet a neutral green.

Store

Length 77 ft. (23.47 m.).
Width 27 ft. (8.23 m.).
Area 2,080 sq. ft. (193.23 sq. m.).
Ceiling height 13 ft. (3.97 m.).
Lamps 9 ft. (2.74 m.) from floor.

Store

5 250-watt clear tungsten lamps.
4 100-watt clear tungsten lamps.
68 10-watt clear tungsten lamps.
Total watts 2,330.
Watts per square foot 1.1.

DELICACIES.

The Specialty Shop in Boston, Fig. 16, has a dark wainscoating about 6 feet (1.83 m.) high; above this the walls are divided into panels; in each of these panels is set a heraldic design, which has been adopted by the proprietor as a trade mark. The ceiling is white, glazed, and divided into polygons by the moulding. The show cases and counters are divided into panels which are practically replicas of the wall panels. The floor is mosaic tile. The lighting system is remarkably in accord with the general scheme. Between adjacent panels is a torch fixture with an upright lamp and diffusing ball. Counter standards, wall brackets and four-arm ceiling fixtures carry bowl-frosted tungsten lamps and pyramidal art glass shades which are finished to match the counter and wall trim. A most pleasing harmony is secured.

As proof that original store layouts are noticed by the general public, the management of this store reports that the lighting is the subject of many favorable remarks, both by local and out-of-town customers.

Store.

Length 72 ft. (21.94 m.).
Width 40 ft. (12.19 m.).
Area 2,880 sq. ft. (267.55 sq. m.).
Ceiling height 20 ft. (6.09 m.).
Lamps 18 ft. (5.48 m.) from floor.
25 60-watt tungsten lamps.
14 25-watt tungsten lamps.
Total watts 1,850.
Watts per square foot 0.65.

CONCLUSION.

A sufficient number of individual installations have been described to indicate quite clearly that the lighting system should blend with the general scheme of decoration. The illuminating equipment, rather than being dazzling, glaring or commonplace, is inconspicuous, and forms a part of the furnishing of the room.

It must be borne in mind that the methods outlined above are not the only correct schemes of lighting to use; often in the laying out of an installation the ideas or desires of the proprietor

will produce considerable deviation from the scheme which would be most in keeping with the period of architecture that is being followed.

From the descriptions given, it can be seen that one is able to apply the commercial diffusers and reflecting devices to almost any class of service. As far as possible the endeavor has been made to discuss stores which had standard equipment, thus showing that there is no necessity for the design of special auxiliaries. Expanding this idea slightly, the authors believe that the stores described are distinctive and yet, with the exception of the carved alabaster bowls, the initial cost is relatively low.

These illustrations might have been continued at great length and an appropriate use found for almost all the equipment listed, but this is obviously out of the question, so the paper can well be closed with the admonition.—In designing the lighting for shops of the class treated in this paper, use discretion in the selection of lighting units and do not offer the prospective customer something which is, on the face of it, purely utilitarian.

The authors desire to thank the photographic bureau of the New York Edison Company, for their assistance in taking photographs and making autochromes and lantern slides.

DISCUSSION.

MR. M. H. FLEXNER: Knowing that the larger units are more efficient than the smaller ones; that just as good results can be accomplished with the larger units—and I am satisfied that equal artistic effects can be obtained as with the smaller ones—I would like to ask Mr. Powell why the clusters seem to be so much in evidence?

MR. S. G. HIBBEN: It seems from the foregoing paper that most of these distinctively lighted stores have had their lighting fixtures built up to be in harmony with the interior decoration. It would be excellent to have fixtures and surrounding decorations planned and built up simultaneously, as is now being done by some of the large department stores. This brings forth the advantages of co-operation between the lighting engineer, and the architect, or particularly the interior decorator.

I believe that of the five or six problems of residence lighting that I come in touch with every day, there are only perhaps one or two that are new installations, and it seems to me that the illuminating engineer is called on for advice only when the room or building is so poorly lighted that something must be done. He is a sort of "lighting doctor," giving a cure rather than a preventative.

It may be of interest to notice how many types of glass appliances are regularly available for distinctive store lighting. Quite often the consumer may make large expenditures for a peculiar or special design of glassware, that might be saved him, were he more thoroughly acquainted with the large variety of illuminating glassware on the market. In briefly mentioning some of these available types, I would call attention to the rapidly increasing number and variety of glass bowls and semi-indirect reflectors, with open tops, or covered with crystal glass plates, or partially closed as in urn shapes.

The decorator can choose from a large variety of period designs, Gothic, Elizabethan, Doric, Adam, Georgian, William Morris, Colonial, etc. One can have glass cylinders, columns with bases and capitols, or glass troughs for outline and cornice lighting. Flat or configurated diffusing glass plates are available for ceiling panels, and plaques for side walls that may serve to replace open bracket lights.

The painting or color decorating of glass is another feature being developed to bring out a relief design by shading, or to give special monograms in glass for fraternal orders, clubs or stores that feature a trade design or coat-of-arms. In distinctive stores, like these described, the gold or silver fixtures, or ones with such finishes may be matched by properly colored glassware.

Mr. R. B. Ely: A paper on distinctive store lighting I think should be encouraged. In some of the illustrations, particularly the restaurant where indirect lighting was employed. I notice that some direct lighting brackets were used. These brackets, I think, would be a distracting feature. In another of the installations, I notice that one lamp has been exposed; this is a particularly bad feature in the system. Take the installation

in the tea room with the silk shades and the wiring, which I believe was exposed. This artistic installation must have been comparatively inexpensive. I also notice a lack of portable lamps in the installations shown. Such lamps I think are coming into more general use. The greatest drawback to their use is the care of the extension cords. However, in some instances where lamps of this kind have been equipped with leaded glass, and other artistic designs, they have been very effective.

Mr. A. L. Powell: Referring to Mr. Flexner's query as to the cause of the clusters being used to such a great extent in the examples shown, I would say that the majority of the installations were designed by the architect. My experience has been that the architect prefers the clusters to the individual lamp for the additional flexibility possible with it, and also for the reason that if one particular lamp burns out, the illumination in a given section will not be materially decreased.

The advisability of combining direct and totally indirect lighting in the restaurant was questioned. It seems that the use of brackets in this particular case, is very feasible, for a relatively large percentage of the patrons are ladies, and they prefer light coming from the side, for the illumination of their faces. In the case in hand, rather dense, shirred silk shades were used, and the glare was absolutely unnoticeable; in fact these units added considerably to the pleasantness of the room.

The use of portable lamps was suggested as an advisable feature of distinctive store lighting. Careful reference will show these in use in Page & Shaw's and the Boston Specialty Shop, and in Schraffts the counter lamps perform the same function.

Mr. Hibben's remarks, as to the use of tinted opalescent glasses, is very timely and there are many cases in which they fit in excellently with the general architectural schemes, and beautiful effects may be produced with them.

The lack of halation of the autochrome plate may be readily explained. The ordinary plate is used with the emulsion side toward the lens; light passes through the emulsion, strikes the glass plate, and being reflected, re-enters the emulsion, producing halation. The autochrome plate is placed in the camera

with the glass side toward the lens and a piece of dull black cardboard against the emulsion; light passes through the plate, and the emulsion and strikes the dull black surface of the card which reflects but very little light, thus reducing halation.

RECENT IMPROVEMENTS IN INCANDESCENT LAMP MANUFACTURE.*

BY WARD HARRISON AND EVAN J. EDWARDS.

Synopsis: 1. Increased mechanical strength of tungsten filaments: The strength of tungsten filament has more than increased 300 per cent. since 1908, and the strength of drawn wire has increased 40 per cent. since 1911. Greater strength permits operation at increased efficiencies at no decrease in total life. 2. Better candle-power maintenance: The use of chemical in the bulbs which has become general during the past year has reduced the blacking of lamps to a marked degree and it is therefore possible to operate them at efficiencies correct from the standpoint of total life with no shortening of the useful life. The performance of chemical lamps is not satisfactory when operated at low efficiencies. 3. Decreased bulb size: Use of chemical has made possible a substantial reduction in bulb size for several lamps. Decreased bulb size reduces manufacturing costs and broadens the application of the lamp. 4. Standardization: During the past year lamp dimensions have been standardized in every particular. The average deviation from the standard is less than one-fourth that of a year ago. 5. Helical filaments: The introduction of the coiled filament makes possible many new forms of lamps which heretofore could not be manufactured. The strength of the filaments is increased by this process and the candle-power maintenance is not affected. The operation of helical filament lamps at high efficiencies and their use in small bulbs rather than poorer performance are the causes of their comparatively low life ratings. The new tubular lamp and the focus type lamp have many applications such as showcase lighting, use in projectors, stereopticons and the like.

The purpose of this paper is to review, briefly, recent improvements in the art of incandescent lamp manufacture and their commercial applications. The more important of these improvements may be grouped under five heads:

(1) Increased mechanical strength; (2) Better candle-power maintenance, obtained by the use of chemical in the bulb; (3) Decreased bulb size; (4) Standardization of lamp dimensions; (5) Production of filaments in helical form.

* A paper read at the seventh annual convention of the Illuminating Engineering Society, Pittsburgh, Pa., September 22-26, 1913.

STRENGTH.

The earliest tungsten-filament lamps were so fragile that, barring those infrequent cases in which the lamps blackened after the first few hours of service, their performance was judged almost entirely on the basis of total life figures. It is well known to the members of this Society that the strength of the pressed-filament lamps steadily increased and with the introduction of the drawn-wire lamp in 1911 a very marked improvement took place. Perhaps some do not realize, however, that the increased strength of drawn wire which has been effected during the past two years is even greater than the difference in strength between the pressed-filament and the drawn-wire filament of 1911. That this is actually the case is shown graphically in Fig. 1 which gives

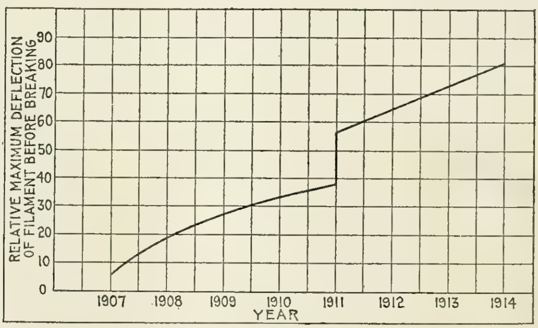


Fig. 1.

the result of transverse tests of filaments manufactured in each year since 1908. The ordinates of this curve are proportional to the distance through which a filament of given dimensions will bend before breaking when stressed by a gradually increasing load. An increase in the strength of a lamp also implies a more homogeneous and uniform filament and the practical result is that the lamps may be operated at a far higher efficiency than before, with no decrease in total life.

CANDLE-POWER MAINTENANCE.

The other factor most important in determining the useful life of an incandescent lamp is the decrease in candle-power with age which takes place as the result of the blackening of the bulb by particles thrown off by the filament. While steady improve-

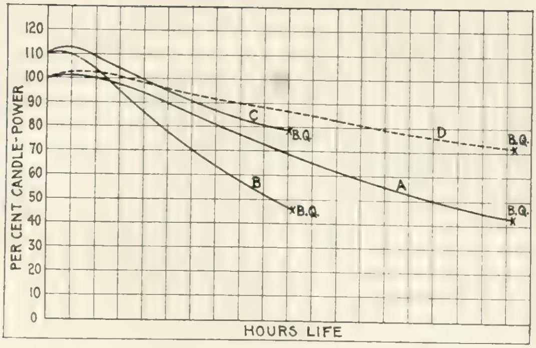


Fig. 2.*

Fig. 3.

*.See lines 12 to 21 on page 547.

1 DATA BOOK SCHED. T-1
2 CLASS Mazda
3 TYPE Straight Side
4 STYLE Large
5 WATTS 60
6 VOLTS 100-130
7 W. P. C 1.12
8 BULB S-21-E2
9 BASE #101
10 REDUCTION FACTOR 78%
11 MAX. OVERALL LENGTH 140 mm 5½"
12 LT. CENTER (FROM BASE) 87 mm 3-7/16"
13 LT. CENTER (FROM BULB END) 43 mm 1-11/16"
14 DIAM. TOP TUBE 5½ or 6 mm
15 LENGTH TOP TUBE 89 mm 3½"
16 CONTRACTION TOP TUBE
17 BUTTON ROD DIAM. 3 mm (2¾-3¼)
18 MAX. DIAM. TOP BUTTON 5½ mm 14/64"
19 MAX. DIAM. BOTTOM BUTTON 8 mm 20/64"
20 NO. TOP SUPPORTS 6
21 TOP SUPPORT METAL
22 TOP SUPPORT DIAM. 4½ mils
23 TOP SUPPORT HOOK 4½-32-7-3 (closed)
24 NO. BOTTOM SUPPORTS 5
25 BOTTOM SUPPORT METAL
26 BOTTOM SUPPORT DIAM. 13 mils
27 BOTTOM SUPPORT HOOK 13-26-8-3 (closed)
28 MAXIMUM SPREAD 29 mm 72/64"
29 SHANK LENGTH 6 mm (4-8)
30 WINDING No. 1
31 GETTER No. 14
32 GETTER POSITION All bottom hooks
33 GETTER AMOUNT
34 DIAM. STEM TUBING 11 mm (10½-11½)
35 DIAM. FLARE 19 mm ¾"
36 MIN. STEM LENGTH 25 mm 1"
37 THICKNESS STEM SEAL 3½ mm
38 WELD 507-16-4-1656 Copper Tube
39 DIAM. BULB NECK 33.4 mm 1-5/16"
40 PAINT FORMULA No.2
41 EXHAUST SCHED. No.1 (5-5-2)
42 AGING Sched. No. 2
43 STD. PKG. QUAN. 100
44 STD. PKG. WEIGHT 33 lbs.
45 WRAPPER A2145
46 INNER CONTAINER M2195
47 OUTER CONTAINER M21420

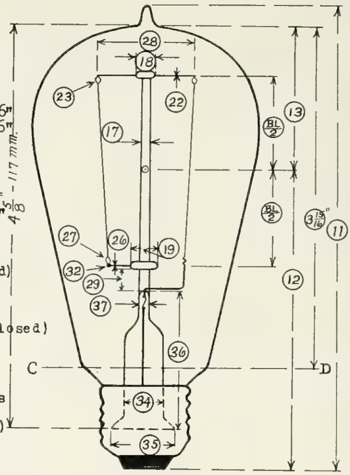


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Fig. 4.

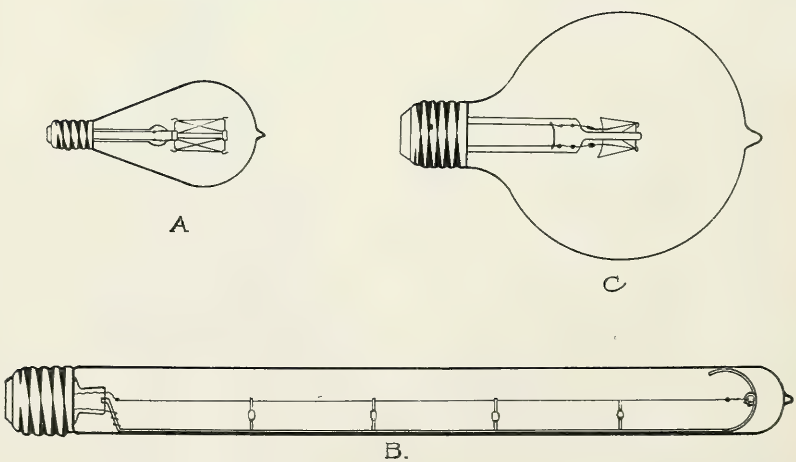


Fig. 5.

ments have been made since 1908 in the direction of diminishing this black deposit, except in the smaller sizes, they have in no way kept pace with the increasing strength and uniformity of the lamp filaments and, owing to this blackening of the bulb, which becomes greatly accelerated at high filament temperatures, it has been found impossible to operate many of the lamps at an efficiency warranted by their total life performance. To be of practical value, therefore, further improvements in the quality of incandescent lamps must necessarily take place in the direction of better candle-power maintenance; hence this phase of the problem has been given particular study during the past two years.

A long series of laboratory experiments led to the introduction of a chemical in the bulb which, under proper conditions, will combine with the black deposit in such a manner as to render it light in color and thus reduce the bulb absorption to a marked degree. For example, the lamp whose performance is shown by curve A in Fig. 2 has a life sufficient so that it might well be operated at an initial efficiency of 1 watt per candle instead of 1.1 watt per candle, its actual rating. However, if burned at the former efficiency, its candle-power life performance would approximate curve B, and at the end of the first few hundred hours of burning, the lamp bulb would be darkened to such an extent that a discriminating user would become dissatisfied and would complain of the short useful life of the lamp. Others, not so careful, would perhaps keep the lamp in service, but at the expense of a serious loss in economy due to the constantly increasing cost of energy per candle-power hour. By the use of the chemical referred to above, the candle-power life performance of the lamp can be improved in accordance with curve C and its useful and total life are made nearly identical. However, if the lamp supplied with chemical were burned under voltage so as to operate at an efficiency as low as 1.1 watts per candle, its performance would not be that shown by the dotted curve D, for the chemical will not operate properly except at high temperatures; at an efficiency of 1.1 watts per candle, the performance of the lamp with chemical would be but little, if at all, superior to that of a lamp not so equipped.

At the present time all lamps above the 40-watt size are sup-

plied with chemical. There is no particular advantage in introducing the chemical into smaller lamps inasmuch as the useful life is still limited by failure of the filament rather than by bulb blackening.

DECREASED BULB SIZE.

Aside from bettering the life performance of the tungsten-filament lamp, much time and effort have been directed toward decreasing the cost of the product and broadening its application The cost of manufacturing and handling the lamps varies almost directly with the bulb size, and the cost of reflectors and similar accessories increases in an even greater ratio; hence, from the standpoint of economy, a substantial decrease in bulb size is equivalent to a considerable increase in life performance or efficiency. Fig. 3 shows the relative sizes of the old 60-watt lamp with the skirted base and the lamp as at present marketed in the S-21 bulb. Owing to the use of chemical in the new 60-watt lamp, it will give as long a useful life as the older type at a decrease of 25 per cent. in renewal cost. The new lamp can also be used in many locations where the size and appearance of the older type rendered it inapplicable. The demand for a 60-watt tungsten-filament lamp in a smaller bulb was probably more pronounced than in the case of any other size, inasmuch as this is the highest wattage which would be used to replace the ordinary carbon lamp unit for unit. At the same time, however, there is a well-marked tendency toward a decrease in size for all lamp bulbs.

STANDARDIZATION.

Of particular interest to the illuminating engineer are the efforts which have been put forth recently toward the standardization of lamp dimensions. Fig. 4 is a factory specification sheet for the new 60-watt lamp, for which forty-seven distinct items have been standardized. The most important standard dimension from the viewpoint of the illuminating engineer is the distance between the center of the light source and the base contact of the lamp, since it is this dimension which has the greatest effect upon the light distribution with various reflectors. The average deviation from the standard in this dimension is now less than one-fourth of the average deviation found a year ago.

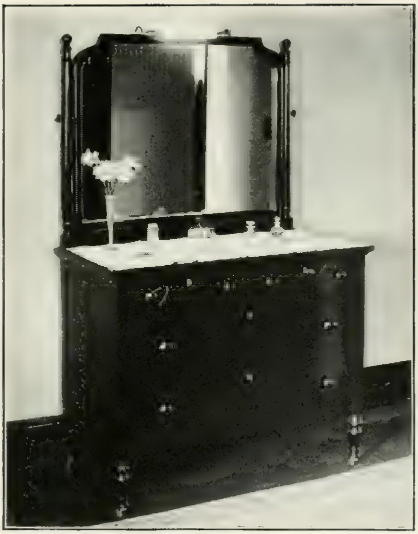


Fig 6.

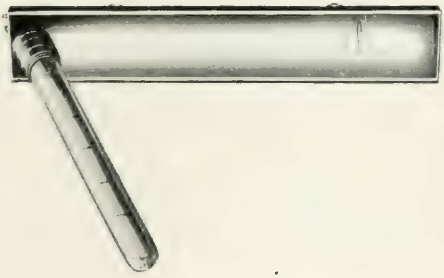


Fig. 7.

Fig. 9.

Fig. 10.

HELICAL FILAMENTS.

Perhaps the most far-reaching of the improvements which have taken place during the past year is the general introduction of the coil filament type of tungsten lamp. It is well known that after the voltage, wattage and efficiency of an incandescent lamp have been determined, all of the filament dimensions are fixed. For example, the old pressed-filament 110-volt, 40-watt lamp when designed to operate at 1.25 watts per candle had a filament diameter of 1.605 mils and a length of 21.25 inches (53.975 cm.). The lamp bulb and filament supports were necessarily of such size and shape as to take care of this length of filament. It was not possible to obtain a concentrated filament lamp, neither could one having a single line of light be manufactured unless the latter were placed in a bulb 22 inches (55.88 cm.) long. Recently it has been found that drawn wire filaments of all sizes can be coiled into the shape of a helical spring; this greatly reduces their overall length and makes practicable a lamp of almost any form desired. This process was first developed in connection with the low-voltage, high-current auto headlight lamps, and later was found practical for even the smallest filament. The diameter of the helical coil is ordinarily not more than seven times the diameter of the filament itself and, therefore, the difference in potential between successive turns is very small, usually about one-tenth of a volt. At this low voltage there is practically no tendency for the current to short-circuit its regular path, even when the coils appear to touch each other.

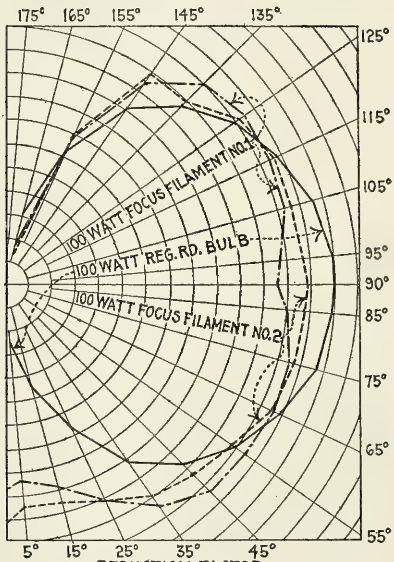
In addition to the above, it has been found that coiled filament lamps are much stronger than those of the standard type, quite as strong, in fact, as the old carbon lamps. This is due in part to the greater ability of the coiled filament to absorb shock and partly because tungsten wire seems to be increased in strength by stressing beyond its elastic limit.

Fig. 5 shows three new types of lamps standardized since the introduction of the coiled filament. Fig. 5-A is a 110-volt, 15-watt lamp having a 1 $^9/_{16}$-inch (39.68 cm.) bulb with candelabra base, and illustrates the possibilities in small high-efficiency light sources.

Fig. 5-B illustrates a lamp with a bulb 1 inch (2.54 cm.) in diameter and 12 inches (30.48 cm.) long that is made in the

25 and 40-watt sizes and is intended primarily for showcase lighting, but which will no doubt find a number of other applications. For example, Fig. 6 shows this lamp in a frosted bulb, so placed over a dresser that it serves as a satisfactory substitute for the two wall brackets often located at either side of the mirror.

Fig. 7 shows a fixture which has been manufactured for use with this lamp in showcase lighting. Its distinctive features are that the socket is supported in such a manner that the lamp can be swung into the position shown, in order to facilitate renewal



REDUCTION FACTOR	
100 WATT REGULAR RD. BULB	81
100 WATT FOCUS FILAMENT NO. 1	98
100 WATT FOCUS FILAMENT NO. 2	89

Fig. 8.

or the cleaning of the reflectors; that the current is carried through successive reflectors by dowel pins fitting into receptacles at the ends of each unit and by wires placed in metal moulding at the back; and that means are provided for securing the reflector to standard showcases of all types. This unit is assembled complete before leaving the factory and, therefore, the installation can be made at a minimum labor cost. "Blanks" or "spacers"

are provided where the high intensity which would be obtained from a continuous line of lamps is not desired. End supports are also manufactured to carry the wires up from the floor of the showcase and to secure them to the first reflector.

Fig. 5-C shows a 100-watt concentrated filament lamp of the focus type which should fulfill a variety of needs. The coiled filament lamps even in this form will give fully as good a life performance as lamps of the regular type when operated under similar conditions. In most cases, however, a high intensity from a very small source is desirable and, for this reason, they are operated at what would be considered over-voltage for the standard lamps and are also frequently placed in smaller bulbs in order to permit their use with reflectors and lenses of moderate dimensions. The focal length of a lens or reflector cannot be less than one-half the diameter of the bulb, if parallel rays of light are to be secured. In consequence of these facts, the life ratings for focus type lamps are considerably lower than for the corresponding standard 110-volt units. In rating coiled filament lamps of all types, efficiency and candle-power values must of necessity be based on total light output rather than upon the intensity in any one direction, for their reduction factor is much higher than for ordinary lamps and is also far from a constant quantity. Fig. 8 shows the distribution curves of three 100-watt lamps, which illustrate the latter point.

The 100-watt focus type lamp will successfully operate small stereopticons for lecture room or residence use and is especially convenient for demonstration work in connection with college courses. It is perfectly steady and requires no rheostat and no attention other than switching on and off. With these lamps it is possible to obtain a brilliant illumination on a small screen for a comparatively low energy consumption.

Fig. 9 illustrates a problem in sign lighting which was readily solved by means of concentrated filament lamps. The use of 250-watt regular lamps in angle reflectors located 4 feet out from the upper edge of the tank was first considered, but it was found that this system would not give satisfaction either from the standpoint of uniform illumination by night or of appearance by day. Two 100-watt, 110-volt lamps in 12-inch (30.48 cm.) silvered parobolic reflectors placed in a weather-proof housing at a dis-

tance of approximately 50 feet (15.24 m.) supplied the illumination for the portion of the tower illustrated in the photograph. Two more units are used to illuminate a similar sign on the opposite side of the tank.

Fig. 10 shows the façade of the Engineering Department Building, Cleveland, Ohio, as it will appear from Euclid Avenue when illuminated by two banks of projectors, each of which will contain nine 250-watt concentrated filament lamps of the focus type. Reflected light from this building is utilized for the illumination of the grounds immediately adjoining.

DISCUSSION.

MR. NORMAN MACBETH: There is one point I would like to bring in here in connection with the discussion on standardization which arose earlier in this meeting. It is agreed that the information bearing on the relative position of the filament in an incandescent lamp and of the lamp in the reflector is something that engineers require in all reports of photometric investigations. I had occasion some time ago to go over the standard specifications of four laboratories, and in checking them up I found that their "a, b, c, d and e" which referred to these relations showed a serious lack of agreement in some, one or all of the various mentioned designations.

It ought to be the duty of the committee of this society to see that these a, b, c, d and e designations have the same meaning with all of these laboratories, and it would also be desirable to provide for other glassware and fixture conditions than those now covered by these letters which refer only to simple reflector designations.

I would like to raise the question on this 80 per cent. so-called smashing point which I remember Dr. Carl Hering stated at one of the earlier meetings of the Philadelphia Section he had determined many years ago by himself, and that same was now a matter of record in the proceedings of the American Institute of Electrical Engineers This was the point at which when considering an average cost for the lamps and for the energy used, a lamp having deteriorated to 80 per cent. of the initial candle-power was no longer economical; that beyond this point the total costs in relation to the

light produced resulted in a new lamp being less expensive. From statements that have been made applying this 80 per cent. to the tungsten lamp it would appear that we have lost sight of the calculation of which this 80 per cent. was the result. It can hardly be possible that with the more expensive tungsten lamps and the very much lower energy cost per light unit that this figure would be true for these lamps.

I would like to ask the authors the probable hour's life represented by the curves in Fig. 2. While this information is not really necessary to bring out the point for which these curves were used information as to the total hours represented by the two curves would considerably widen the use of this one illustration.

Mr. W. F. Little: The standardization of filament dimensions and of the location of light center in incandescent lamps is perhaps of more importance to the lamp purchaser than to the manufacturer, as the variation from standard conditions might be such as to change the characteristic of an intensive reflector to that of an extensive reflector. As representing the purchaser, the Electrical Testing Laboratories has for some time past urged close adherence to the dimensions as laid down by the manufacturer, and has included dimensional requirements in its inspection criteria.

Mr. G. H. Stickney: There should be no loss in efficiency from light falling upon filament surfaces. Any heat transmitted from one part of the filament to another in this manner would simply go into raising the temperature of the filament and therefore be returned as light. (On account of the thinness of filaments and the heat conduction of the material, it would hardly be possible for one side of the wire to attain a perceptibly higher temperature than the other.)

We cannot over-estimate the importance to the art which may be derived from our ability to concentrate the filament, as referred to in the paper. As referred to in previous discussion, this has introduced a considerable number of new applications for incandescent lamps and created some entirely new fields of lighting. The importance of this has been appreciated for some time and we have made a very considerable study of the uses

of point sources of light. In the long run, however, I am not sure that the point source may not prove of even greater importance in handling problems of interior lighting, since it offers an opportunity for improved control of the light in obtaining new and desirable effects.

Mr. L. C. Porter: In speaking of the applications of the new focus type lamp, there are three fields which seem to open up considerable use for this lamp. One is in theater lighting. Some of the larger sized lamps have been used for flood lights in theaters. By the use of such lamps and large parabolic reflectors we can get effects which are hard to obtain with the arc. The incandescent lamp can be very easily and evenly dimmed or brought up to full candle-power. Focus type lamps have been used with parabolic reflectors to throw a sheet of light over each individual drop curtain, in that way obtaining much more satisfactory lighting effects than previously were obtained by the use of the arc. The light is steady and considerable power economy is obtained by its use.

This lamp is also being used in moving pictures for home use, to do away with the fire risk and auxiliary apparatus necessary with the arc.

Another field in which a little experimenting has been done is in signal work. Experiments have been conducted where signals have been transmitted over a distance of 20 miles with a concentrated filament tungsten lamp and parabolic reflector. These signals were read without the use of glasses, both clear and colored screens being used over the reflectors.

Still another field which is opening up is in headlights, especially for locomotive headlights. There is at the present time considerable agitation throughout the country on the question of locomotive headlights. Several states have passed legislation requiring locomotives to carry more powerful headlights; in others this subject is pending. Some of the roads, especially those with double tracks equipped with block systems, object to using the very powerful arc headlights. Between the arc and the oil lamp comes the incandescent. It seems very highly probable that a 6-volt focus type of incandescent lamp (operated either by storage batteries or by a small 6-volt turbo-

generator outfit) will have large application for locomotive headlights in the near future.

DR. M. G. LLOYD: The efficiency of an incandescent filament depends upon the temperature of the surface which is emitting radiation. The question arises as to whether with a helical filament the surface temperature can be as high as with a straight filament having the same life; or whether the life can be as long for the same surface temperature. In a straight filament the highest temperature is in the interior of the wire and it is only the temperature of the surface which affects either radiation or evaporation. In a helical filament the highest temperature will probably be found on the surface of the wire in the interior of the coil. This surface is exposed sufficiently to permit evaporation, but not sufficiently to give out radiation. The temperature of the exterior surface will as before determine the efficiency; whereas, the temperature of the interior surface will probably determine the life. For the same temperature of the external surface it would, consequently, seem possible that the evaporation would be greater, and hence the life of the filament shortened as compared with a straight filament.* Practical experience seems to indicate that this effect is not appreciable.

MR. H. CALVERT: Referring to Fig. 2, I note that the figures representing the hours life have been omitted. I think it would be much more interesting and instructive if these figures could be inserted. The question of the blackening of the lamp bulbs has recently taken on a new and interesting phase. A number of the central stations have recently adopted the policy of giving free renewals on certain sizes of tungsten lamps. Formerly, when the consumer had to purchase each lamp he would keep it in use until it got so black that he could get but little light. Now, under the new ruling, he is entitled to free renewals, and the question arises, at what point in the life of the lamp is the company justified in giving a new lamp? It is generally not so much the decrease in the actual candle-power of the lamp which influences him in bringing the old lamp to the central station, as

* Dr. Irving Langmuir has since stated that in the half-watt lamp using the helical form of filament the interior surface is at a temperature about 12 degrees higher than the exterior surface.

it is the blackened appearance of the bulb. I would therefore like to ask the authors what, in their opinion, is the limit of this term "useful life" which they use, and at what point, in their opinion, are the various companies justified in giving free renewals?

Dr. R. E. Myers: This is a very interesting paper which the authors have given us and there is very little to add. The principal features upon which the recent improvements depend have been given in a very able way.

Greater emphasis might be laid on the fact that the latest developments in the standard lines of tungsten lamps, which probably represent over 90 per cent. of this product, are due to improvements in the filament and to the use of chemicals.

The improvements in filament are of two kinds. First, we are now using a drawn wire which has a much greater tensile strength than the pressed filament of the earlier tungsten lamp. This gives low manufacturing shrinkage and reduced cost. Second, the present filament is much stronger throughout its burning than the older filament. This is due to certain changes of which I am not at liberty to speak owing to trade reasons. These changes, however, are of the utmost importance in the life of the lamps of lower wattage of the standard line.

Large improvements in efficiency have certainly been made by the use of chemicals in the lamp. However, I believe that still greater ones are yet to come. This field of research will doubtless prove a very fertile one and I think that in a great many cases this type of lamp in actual use will prove equal to or even superior to the new gas filled lamps.

The authors may have to change their opinion regarding the use of chemicals in the smaller lamps. Recent experiments tend to prove that certain chemicals can be used to advantage in these also.

Dr. H. E. Ives: Another application of these helical filaments—not a commercial application—is in photometric research. In this a valuable consideration is the ability to obtain a wide range of illumination without resorting to sector disks or absorbing screens. With the ordinary carbon lamp it is impossible to get nearer the photometric screen than about 10 inches, because

the inverse square law can no longer be applied. If, however the light is compressed into these little coils it is possible to push the light up until the bulb actually strikes the receiving surface without involving errors from inverse square law calculations which means that one can increase the range of illumination at least 100 times over what was available before. In this connection I have had, through the kindness of Mr. Stickney, several of these lamps to try out and I have found them extremely convenient in so far as the ability to obtain great variation of illumination is concerned.

One question, however, I have not been able to investigate. I would like to ask the authors of this paper as to the performance of these lamps. I suspect that the high voltage lamp would be apt to be unsteady and unreliable because of the number of filament supports. The low voltage, however, might be very reliable indeed. I should like to ask the authors if they have any data that might enable us to make comparisons as to steadiness with the usual photometric standards.

Mr. J. R. Cravath: I would like to ask what the effect of coiling the filament in helical form has upon the efficiency. Is there any loss of efficiency due to the shading effect of one convolution on the next?

Mr. V. R. Lansingh: The use of the helical coil filament giving a very small body of light will be particularly useful in the design of reflectors using specular reflection, such as prismatic, mirrored, etc. One of the greatest difficulties in a design of that character is the size of the source of light. The ordinary tungsten lamp filament may be considered as a transparent cylinder, and this introduces a number of problems, one of which is the shape of prisms, etc., in the case of prismatic glassware. The ordinary prism, as you probably all know, is 90 degrees. It is possible, however, to design prisms of different shapes, so that a higher efficiency is obtained with the present type lamp filament than given by the 90 degree prism. For example, one manufacturer uses a parabolic prism on the outside of the reflector.

With the introduction, however, of the new filament, it will be possible to obtain far higher efficiency than before, and this

will be particularly valuable where broad distributions of light are wanted, such as in street lighting. We may therefore look probably for a large advance in the design of reflectors from now on with the new filament lamp.

MR. L. J. LEWINSON: Referring once again to the light colored discoloration due to the chemical, I would like to ask the authors whether the manufacturers consider it necessary to ship from the factory new lamps, the bulbs of which already manifest this discoloration to some extent.

MR. H. S. DUNNING: Just a point as to the return of lamps to central stations: It is probable that for some time lamps of the 150-watt or larger sizes may be returned because they show a white deposit on the bulb. It has been our experience backed by accurate measurements that in most cases the appearance of this white deposit does not necessarily mean a large decrease in candle-power, and quite often it will be found that the candle-power has not decreased at all. Some of these lamps have a most interesting performance on life test. We have found cases in which lamps after operating for an extended period at approximately 100 per cent. of their initial candle-power seem to lose candle-power for a time and later come back to approximately normal rating. These changes have been investigated very closely and it has been found that they are not due to either photometric or other test errors. I think, therefore, that a word of caution is in order against the discarding of such lamps, simply because they show an unusual discoloration of the bulb.

DR. M. G. LLOYD: The statement of Mr. Harrison that the smashing point does not depend upon the relative cost of energy and renewals involves an assumption that should be made clear. It does not apply to lamps operated at rated voltage, since it is clear that if the cost of renewal was merely nominal, the smashing point would be reached as soon as the candle-power has fallen off appreciably, say to 95 per cent. Mr. Harrison's assumption is that the lamp shall be operated at the most economical efficiency and the lower the cost of renewals the lower should be the specific consumption and the higher the voltage at which a given lamp should be operated. Since this is a con-

dition that cannot be conveniently carried out in practise, the statement that the smashing point is independent of the cost of renewals and the cost of energy is also one that does not apply to practical conditions.

MR. WARD HARRISON (In reply): Mr. Lewison inquires in what way the characteristics of the coiled filament lamps differ from those having the standard form of filament. There is a slight variation in the performance curves, but the principal difference is in the manufacturing data; *i. e.,* the length of filament required, and the diameter for a given candle-power, voltage and efficiency.

The abscissae of the curves in Fig. 2 were not indicated as actual hours of life because the relative performance with a given change in voltage is independent of the actual hours represented by the curve. A typical lamp giving 2,000 hours life to burn out without "getter" would have a life of about 1,000 hours if the voltage were raised 10 per cent. Under those conditions the introduction of the "getter" would result in better candle-power maintenance but the life to burn out would still be about 1,000 hours. Actual quantitative data on actual lamp performance were given by Mr. Lewinson.

It has long been considered that the smashing point of incandescent lamps for most economical operation depends upon the rate for energy and the cost of lamps, as well on the form of the candle-power depreciation curve. More recent investigations show that this smashing point, a certain percentage of initial candle-power, is determined solely by the performance of the lamp. The most economical life of the lamp in hours, on the other hand, is determined by the cost of lamp renewals and the energy rate, and this life can be secured in practise by selecting a lamp of the correct efficiency. If the proper choice of initial efficiency is made, the lamp will be found to have dropped in candle-power to the smashing point at the end of the period representing its economical life as determined above. A full discussion of this subject is given in a technical bulletin issued by the engineering department, National Lamp Works of the General Electric Company.

The answer to the question raised by Dr. Ives in regard to

using concentrated filament lamps as standards is suggested by Fig. 8 of the paper. Curves 1 and 2 are both on concentrated filament lamps built to fulfill the same specifications and yet it is seen that the candle-power curves are considerably different. Inasmuch as a very slight change in the relative position of filaments will cause a marked change in the shading effect such lamps can scarcely be used as standards. The filament may sag slightly after the lamp has been burning for a short period and thus materially change the distribution curve, although the total light flux and efficiency would not be affected to any extent. This well illustrates the necessity of arriving at something better than simply a watt per horizontal candle-power rating for incandescent units.

Mr. Macbeth's remarks were most timely as to the desirability of having some uniform system of designating the position of the lamp filaments relative to the reflector in recording data on photometric tests. I am glad to say in this connection that we have taken the matter up with several other laboratories and have agreed upon a system of lettering which will be uniform and which no doubt will eliminate much of the confusion which has existed heretofore. These designations are of course purely arbitrary.

Mr. Cravath and Dr. Lloyd spoke about the rise in temperature of the inner surface of the filament because of the tendency of one portion of the coil to shade another. This effect so far as has been determined is very slight. As Mr. Stickney has said, if the radiant energy does not escape at once, it is merely reflected from the hot surface of the filament one or more times before passing out of the helix. If this radiant energy would be absorbed instead of being reflected, it would of course raise the filament temperature somewhat, but the net change would certainly be very slight, since the difference in temperature between two points on the same cross section of filament is necessarily small.

There is one more point, and that is in regard to the discoloration of the bulb of "getter" lamps without a material decrease in light output, which was commented upon by one of the speakers. This phenomenon is entirely reasonable as in

those cases the deposit is light in color, similar in fact to an opal dip or frosting. It may of course have a considerable effect on the intensity of the lamp in any one direction, but the decrease in total light flux should not exceed a few per cent. The tendency of these lamps to be slightly erratic is, of course, not surprising; however, we believe that the improvement in this respect during the past few months has been marked.

Mr. J. W. Howell: Most of the things that I had in mind to speak about have already been mentioned either by Mr. Harrison and Mr. Edwards or in the report of your Committee on Progress, so all I can do will be to give you a little further information on some of the things which you have already been considering. In the time in which we live the most rapid advance in the art of light producing ever known is being made. Even since incandescent lamps have been made one of their characteristics has been that the lamps with thin filaments end their life by breaking, without much discoloration of the bulb, while lamps with thick filaments and high candle-power blacken the bulb and become useless before the bulb breaks. So we have never been able to obtain the good results which we should get from thick filament lamps. Much progress has been made in the last two years in preventing the blackening of the bulbs and thus utilizing the longer life of the thick filament. A year ago we talked and discussed the action of what we call vacuum getters on lamps. That same line of work has been conducted during the past year and very great advances have been made.

There are two reasons why a thick filament lamp gets blacker than a thin filament lamp: one of the reasons is that it lives longer and consequently has more time to get black in; the second is the blackening is proportional to the surface of the filament, and inversely to the size of the bulb. To be properly designed the surface of the lamp bulb should be proportional to the surface of the filament. But that cannot be. A 10-watt lamp has a diameter of 2⅛ inches, that would require a 100-watt lamp to be 10 times that diameter of 21 inches; which would be impossible.

During the year we have made very great advances in these large lamps.

I have just shown a report of some life tests on some hundred-watt hundred volt lamps. These lamps are tested at 9/10ths of a watt per candle. Their normal burning efficiency is one watt per candle. Of these tests only two were completed at the time the table was made up, which is quite recently. In the two of the tests the lamps burned a thousand hours at 9/10ths of a watt per candle and at the end of that time were up to their initial performance. At the end of 3,100 hours they should show 99 per cent. of their full candle-power.

I also have a report of a test of 250-watt 100-volt lamps. The lamps were not experimental lamps; they are not made in the laboratory; every lamp was taken from the regular factory stock, taken without any selection whatever. The lamps were burned at ¾ of a watt per candle on life tests. After 500 hours burning they were pretty close to 90 per cent. candle-power of initial candle-power. If they had been burned at their normal efficiency, which is one watt per candle, their life would have been 9.6 as long. So that when they were down to 90 per cent. of their candle-power, burning on a normal voltage, they would have burned over 4,000 hours. That shows very great improvement in lamps of that type.

I also have a diagram showing a test on a 400-watt lamp taken right out of stock, without any selection whatever. The lamp was started on test in September of last year, just a year ago. When the diagram was made out, the lamp had burned 6,000 hours and showed about 92.5 per cent. of its initial candle-power. The lamp when I left to attend this convention had burned 7,000 hours, practically unchanged at this date.

These reports indicate the great improvement which has been made in the high candle-power lamps. It is the established procedure in business that as improvements are made the efficiency is increased. Otherwise the economy of the lamp would not be realized. It is considered at the present that a thousand hours of useful commercial life is proper and best, so that as lamps come to give long lives like that their efficiency is increased so that the laboratory life is about 1,300 or 1,400 hours, which would give in commercial practice a life of about 1,000 hours.

There has been under way, during the last two years a very

remarkable piece of work in the research laboratory of the General Electric Company at Schenectady. The work has been done by Dr. Langmuir and his assistants, one of whom is here today, and it was my purpose to tell you a good deal about the work at this meeting but unfortunately Dr. Langmuir's description has had to be postponed until next month. A half-watt per candle lamp, —that lamp is the result of Dr. Langmuir's work. It is a lamp such as we have here, an incandescent tungsten filament lamp, the bulb of which is filled with nitrogen. Now the nitrogen has several effects on the lamp; some are good and some are bad. The bad one is that it cools the filament and so reduces the candle-power. When a gas is introduced into a lamp vacuum it cools the filament always. In a thin filament lamp the cooling effect is greater than in thick filament lamps. So the thicker the filament the more benefit is to be had from the nitrogen gas in the bulb. In the present state of our knowledge we get our one half-watt per candle lamp at about 12 amperes; while at 20 amperes we get 0.4-watt-per candle. Tests of such 20 ampere lamps, have been made at 0.4-watt per candle. Some of these lamps have burned 2,000 hours. The large lamp here before you is a 20-ampere 112-volt lamp; it consumes about 2,500 watts, and gives 5,000 candle-power. It is supposed to be the largest incandescent lamp which has ever been made. Unfortunately the lamp has a little crack in the glass, which has allowed a little air to mix with the nitrogen; so that when it is lighted it will show a faint cloud of tungsten oxide, and it is not an effective lamp. The future of that lamp, gentlemen, you may all theorize on as much as I can. You know what the introduction into the art of lamps of larger sizes than have been made before means; and the policy has been established to add to our present line of lamps up to this 5,000 candle-power size, or higher if necessary. If the commercial people want a 10,000 candle-power lamp they can have it; there is no limit that we know of yet.

That lamp which you see burning is a 500 candle-power lamp, at 112 volts. Its light is very concentrated and very intense. The lamp is of a size which does not realize a half-watt per candle: in fact it is about a 0.6 watt per candle lamp.

Here is a larger lamp one which burns at one-half-watt per

candle; it is a good lamp. The air is leaking into that bulb; its action will not continue very long, but while it is continuing it is destroying the filament. I don't know what will happen to the lamp with the air in it.

There has been another matter which has been alluded to in the report of the Committee on Progress and also in the paper, by Messrs. Harrison and Edwards, which I consider very important and that is what they call a single size wire. It simply means that the art of drawing tungsten wire has been reduced to such a fine degree, such an efficiency, that the wire can be drawn to absolutely the size desired. Of course when you consider the matter if the dies are proper and of the right size the wire drawn should be the right size. They are the right size. And at the present the wire in the filament is of the right length and diameter; all of the lamps made for a given voltage are that voltage. If a factory is producing lamps that are of a given voltage and the photometer disagrees with the marking, the photometer is wrong. (Laughter.) Gentlemen, that is a fact. It is true that the grading is better than the photometer. If we find that the lamps test off voltage, in nine cases out of 10 the difficulty is with the photometer and not with the lamps. As you know some of our customers in the country buy their lamps on specifications as to voltage and candle power, and the lamps submitted during the last six months or more to those customers are lamps which have never been photometered; they are lamps made for a definite voltage and candle power, and the result is that they are closer to rating than were the previous photometered lamps.

Mr. L. J. Lewinson: In order to further emphasize some of the points brought up in the paper, a table and a diagram are submitted herewith. The table comprises a summary of the various watts per candle ratings of tungsten lamps in force in this country during the past two years. It is noted that with the exception of the very smallest sizes great strides in efficient improvement have been made. The diagram shows the very remarkable improvement life and efficiency of one particular size—the 250-watt lamp. The heavy horizontal lines represent the average life value during the periods indicated. It is seen that

EFFICIENCY ADJUSTMENT—TUNGSTEN LAMPS.

Wattage ratings	Watts-per-candle rating 1911	April 1912	September 1912	May 1913
15 watts	1.31	1.31	1.30	1.30
20 "	1.31	1.28	1.25	1.25
25 "	1.31	1.23	1.17	1.17
40 "	1.23	1.18	1.17	1.17
60 "	1.18	1.16	1.16	1.12
100 "	1.18	1.13	1.13	1.08
150 "	1.18	1.12	1.12	1.03
250 "	1.13	1.10	1.00	1.00
400 "	1.13	1.10	1.00	1.00
500 "	1.13	1.10	1.00	1.00

early in 1911 the useful life of these lamps was about 700 hours at 1.13 watt-per-candle. In October of the same year a bulb blackening preventive was introduced which had the effect of increas-

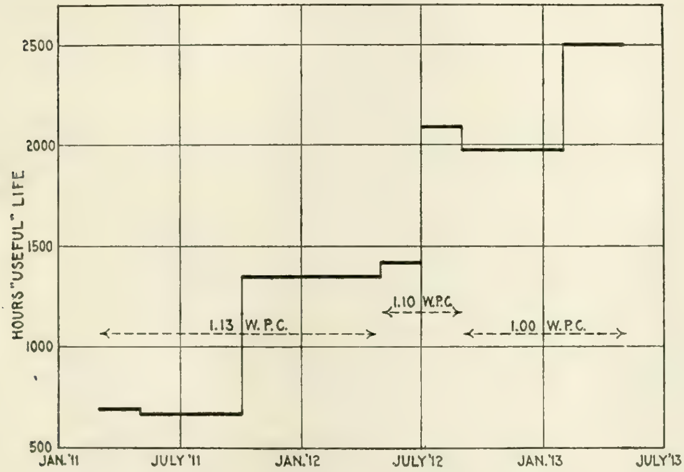


Diagram A.—Improvement in useful life of 250-watt tungsten lamps.

ing the life to 1,350 hours. By May, 1912, the manufacture of this type of lamp had been so improved that it was possible to raise the efficiency, lowering the watts per candle to 1.10, without deleterious effect upon the life. In July, 1912, a new bulb blackening preventive was adopted, increasing the life to nearly 2,100 hours. In September of the same year a new form of construction was adopted. It was found possible to still further in-

crease the efficiency, to correspond to 1.0-watt per candle with only a very slight loss in life. In February, 1913, the form of construction was again changed, with a resultant life of 2,500 hours. It is seen then that during the brief span of two years the watts per candle rating has been reduced from 1.13 to 1.10 with an increase of 250 per cent. in useful life. Assuming all life values to be corrected to one standard watt per candle value, the inherent improvement in the life of this particular type of lamps has been nearly 700 hours. All life values quoted above are to be considered as life to 80 per cent. or prior burn-out.

Illuminating Engineering Society

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Illuminating Engineering Society

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COLORADO:	Denver	G. E. Williamson, Denver Gas & Electric Company, Denver, Colo.
GEORGIA:	Atlanta	William Rawson Collier, Georgia Railway & Light Company, Atlanta, Ga.
MINNESOTA:	Minneapolis	G. D. Shepardson, University of Minnesota, Minneapolis, Minn.
	St. Paul	A. L. Abbott, 185 East 4th Street, St. Paul, Minn.
OHIO:	Cleveland	Ward Harrison, Nela Park, Cleveland, Ohio.
WASHINGTON:	Seattle	Fred. A. Osborn, University of Washington, Seattle, Wash.

TRANSACTIONS

OF THE

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VOL. VIII — DECEMBER, 1913 — No. 9

Council Notes.

A regular meeting of the Council was held December 12, 1913, in the general offices of the society, 29 West 39th Street, New York. In attendance were: C. O. Bond, president; J. W. Cowles, Ward Harrison, Joseph D. Israel, general secretary; V. R. Lansingh, C. A. Littlefield, L. B. Marks, treasurer; Preston S. Millar, J. Arnold Norcross, C. J. Russell, W. J. Serrill and G. H. Stickney.

The meeting was called to order at 10:35 A. M. by President Bond.

To supplement the sixth paragraph of the minutes of the October Council meeting (page 7 of the minutes of the present administration) the following amendment was adopted:

The Illuminating Engineering Society hereby expresses its adherence and support, through the United States National Committee, to the International Commission on Illumination; and as an earnest of its attitude herewith appropriates its assigned quota of expenses for the ensuing year, $100.00, to the use of the said National Committee.

With the foregoing amendment the October minutes were adopted.

Mr. Israel reported that the total membership of the society as of December 10, including applications and resignations to be presented at the meeting, was 1,401. Counting the applications for sustaining membership presented at the meeting there were 31 sustaining members, which are not included in the foregoing membership figure. The expenditures for the first two months of the present fiscal year was said to have totaled $3,217.31.

Vouchers Nos. 1513 to 1548 inclusive, aggregating $1,048.46, were authorized paid subject to subsequent approval by the Finance Committee.

In accordance with recommendations contained in a report from the Finance Committee it was voted (1) to transfer the account of the society now in the Lincoln National Bank to the Central Trust Company at Madison Avenue and 42nd Street, New York, N. Y., provided interest at 2½ per cent. on the bank balance cannot be obtained from the Lincoln National Bank; the Central Trust Company has agreed to pay the society interest at that rate on balances of not less than $1,000 and not more than $10,000; (2) to increase the monthly salary of Miss Claire Goldblatt, an assistant in the office of the society, from $44 to $54, and (3) to authorize the printing of another edition of 10,000 copies of the illumination primer, "Light: Its Use and Misuse."

Verbal reports of progress were received from the following committees: Sustaining Membership, Education, and Section Development. The reports were accepted with commentation.

Mr. C. A. Littlefield, chairman of the 1913 Convention Committee, presented the final report of his committee. The

receipts and disbursements were said to have amounted to $1,875 and $1,705.08 respectively. Accompanying the report was a scrap book outlining the way the convention was conducted and including samples of various letters and literature which had been issued.

Whereupon it was resolved to extend to the committee a very hearty vote of thanks for the able and successful manner in which the 1913 convention—probably the best convention ever held by the society—was conducted.

Resolved, that a special vote of thanks be transmitted to the Papers Committee of the previous administration for having arranged for the 1913 convention an excellent program of papers, which has been pronounced the best balanced set of papers ever presented before a meeting of the society.

A vote of thanks was extended to Mr. G. H. Stickney for his able presentation of a lecture on industrial lighting at a session of the International Exposition of Safety and Sanitation held under the auspices of the American Museum of Safety in the Grand Central Palace.

Mr. G. H. Stickney reported that the contributions referred to in the foregoing paragraph had been sent to the office of the society and that he proposed to submit bills for installing the exhibit to be paid out of this fund. This procedure was accepted and accordingly the Council voted to authorize payment of such bills up to $300, the amount of the fund.

It was resolved that a vote of thanks be sent to the members of the Lighting Exhibit Committee for their excellent services in arranging the foregoing exhibit, and to the Electrical Testing Laboratories for its kind assistance in the work.

Reports on section activities were received from the following vice-presidents: J. W. Cowles, New England; G. H. Stickney, New York; W. J. Serrill, Philadelphia; Ward Harrison, Pittsburgh; and J. R. Cravath, Chicago.

Mr. G. H. Stickney reported informally on the work of the Papers Committee of which he is chairman.

The following appointments to committees were confirmed:

Nomenclature and Standards: C. H. Sharp, Louis Bell, C. O. Bond, E. P. Hyde, H. E. Ives, L. B. Marks, A. S. McAllister, E. B. Rosa; advisory members: Andre Blondel, Hans Bunte, Vivian B. Lewes and C. C. Paterson.

Section Development: Alan Bright, C. M. Cole, L. B. Eichengreen, J. B. Jackson, C. L. Law.

Advertising: B. F. Fisher, Jr., F. H. Gale, J. C. McQuiston and Robert F. Pierce.

Popular Lectures: Sub-Committee on Residence Lighting: E. J. Edwards, chairman; C. R. Clifford, S. G. Hibben, J. W. Lee and J. L. Wiltse; Sub-Committee on Store Lighting: A. L. Powell, chairman; J. M. Coles, F. H. Gilpin, D. A. Bowen, C. B. Graves and A. S. Ives; Sub-Committee on Industrial Lighting: G. C. Keech, chairman; Ward Harrison, C. E. Stephens, A. J. Sweet, M. H. Flexner, C. A. Luther and H. W. Shalling; Sub-Committee on Office Lighting: C. E. Clewell, chairman; C. L. Law, J. G. Henninger, T. W. Scofield.

Papers: Theodore H. Piser and Professor W. E. Wickenden.

The resignation of Albert Jackson Marshall as a director of the society was accepted. It was voted to extend Mr. Marshall a vote of thanks for his past services to the society.

Mr. J. Arnold Norcross, secretary and treasurer of the New Haven Gas Light

Company, 80 Crown Street, New Haven, Conn., was elected a director of the society to fulfill the unexpired term of the vacancy caused by the election of Mr. C. O. Bond to the presidency, *viz.*, December 12, 1913, to September 30, 1915.

Mr. Alten S. Miller, vice-president of Humphreys & Miller, Inc., 165 Broadway, New York, N. Y., was elected a director to fulfill the unexpired term of Mr. Albert Jackson Marshall, resigned, *viz.*, from December 12, 1913, to September 30, 1914.

Mention was made of a letter received from Mr. W. F. Durand, executive secretary of the International Engineering Congress which is to be held in San Francisco in 1915. This letter stated that the Congress is backed by the five oldest engineering societies and that the papers to be presented before the congress which might be of interest to illuminating engineers would be included with some general papers in a miscellaneous volume, the contents and character of which had not yet been determined.

Invitations to hold the 1914 Convention of the society in Cleveland were received from local civic, professional and commercial organizations and, conjointly, from representatives of a number of manufacturing companies and several colleges.

The president was directed to appoint a special committee to consider the time and place of the 1914 convention. The aforementioned invitations were referred to that committee.

It was voted to hold the regular meetings of the Council during the rest of the present administration on the afternoon of the second Thursday of the month at 2 P. M.

The meeting adjourned at 1:25 P. M.

Section Notes.

CHICAGO SECTION

The December meeting of the Chicago Section was held on the 10th at the residence of Mr. A. D. Curtis of the National X-Ray Reflector Co. Mr. Curtis read a paper entitled "Five Years Progress in the Indirect Lighting of the Home." A number of different types of lighting appliances for residence lighting was shown in connection with the paper. Seventy-five members and guests were present.

At the January meeting, which will be held on the 27th, at the Art Institute, Mr. J. B. Jackson will read a paper entitled "Planning Lighting Installations." Mr. W. A. Durgin will give the second one of his 20-minute talks on the "The Fundamentals of Illumination."

NEW ENGLAND SECTION

A meeting of the New England Section was held in the Auditorium of the Edison Illuminating Company of Boston, December 9, 1913. Mr. L. A. Hawkins of the Research Laboratory of the General Electric Company read a paper entitled "The Nitrogen-Filled Lamp and Its Possibilities." One hundred and forty members and guests were present.

NEW YORK SECTION

A regular meeting of the New York Section was held in the United Engineering Societies Building, 29 West 39th Street, New York, December 11, 1913. Two papers, "Reasons for Styles in Architecture" and "Periods of Architecture as Applied to Fixture Design," were presented by Messrs. Frank E. Wallace and Howard E. Watkins, respectively. Both papers called forth some very interesting discussions. One hundred and forty members and 40 guests were present. A dinner preced-

ing the meeting at Keens' Chop House in West 36th Street, was attended by 30 members and guests.

PHILADELPHIA SECTION

The Philadelphia Section held a meeting December 8 at the Engineers Club, 1317 Spruce Street. The following papers were presented: "Railway Car Lighting" by G. H. Hulse, "The Measurement of Brightness and Its Significance" by Dr. H. E. Ives, and "The Mercury Quartz Tube Lamp" by Mr. M. D. Bucknam. A 220-volt quartz tube lamp was demonstrated by Mr. H. Calvert. Mr. J. Stilwell exhibited some water sterilizing apparatus. One hundred and sixty-five members and guests attended the meeting. At a dinner at the Engineers Club preceding the meeting 50 members and guests were present.

The program of meetings and papers for the rest of the season is as follows:

FRIDAY, JANUARY 6.

"Deficiencies of the Method of Flicker for the Photometry of Lights of Different Colors."

By Prof. C. E. Ferree.

SATURDAY, FEBRUARY 7.

Meeting under the Auspices of Drexel Institute.

"Light and How to Use It."

By Mr. C. O. Bond, President of I. E. S.

WEDNESDAY, FEBRUARY 18.

Joint Meeting with Franklin Institute.

"Artificial Daylight."

By Dr. Herbert E. Ives.

FRIDAY, MARCH 20.

"Lighting and Signalling Systems of Subways."

By Mr. F. D. Bartlett.

"The Sun—The Master Lamp."

By Prof. James Barnes.

THURSDAY, APRIL 9.

Joint Meeting with Franklin Institute.

"Recent Developments in the Art of Illumination."

By Mr. Preston S. Millar.

FRIDAY, APRIL 17.

"The Structure of the Normal Eye and its Ability to Protect Itself Against Ordinary Light."

By Dr. Wendell Reber.

"Glassware for Illumination and Other Purposes."

By Mr. James Gillinder.

FRIDAY, MAY 15.

Mass Meeting of all the Engineering Societies of Philadelphia and Vicinity.

Special Program to be arranged and to include an address on

"The Relation of Engineers to the Progress of Civilization."

By Dr. Chas. Proteus Steinmetz.

PITTSBURGH SECTION

The November meeting was held on the 28th in Thaw Hall of the University of Pittsburgh. Dean F. L. Bishop of the Engineering School of the latter university gave a lecture on "The Physics of Lighting." Fifty-three members and guests were present.

On December 12, the Pittsburgh Section held a joint session with the local chapter of the American Institute of Electrical Engineers in the Auditorium of the Engineers Society of Western Pennsylvania. One hundred and thirty-two members and guests of both societies were present. The following papers were presented: "A Problem in Boulevard Lighting" by J. M. Froelich; "Variables in Street Lighting" by J. F. Martin; and "Some Aspects of Free Lamp Renewals" by T. F. Campbell.

The following program of papers and meetings has been arranged:

JANUARY 16TH.

(1) "A Photographic Analysis of Diffusing Units with Varying Indirect Component" by E. B. Rowe and H. H. Magdsick of the National Electric Lamp Association, Cleveland, Ohio. The speakers will have photometric curves on present types of commercial "semi-direct" glassware showing the effect or variations in contour, density and lamp arrangement on absorption and transmission, as well as on reflecting and illuminating efficiency.

(2) "The Relation of the Engineer to the Problems of Fixture Design" by A. B. Wilson and F. J. Blaschke of the National Electric Lamp Association, Cleveland, Ohio. This paper deals with the object of a lighting installation, explains what a fixture really is and illustrates its correct and incorrect application, mentions co-operation between engineer and fixture maker, states how designers' ideas are carried out. It also shows how the lighting fixture is an element in the advancement of the art of illumination.

FEBRUARY 13TH.

"Lighting of Railroad Yards" by A. C. Cotton of the Pennsylvania Railroad and Harold Kirschberg of the Lighting Specialties Company. The authors will discuss the various elements entering into the lighting of track scales and classification yards, together with the difficulties experienced with same, and how they are best overcome.

MARCH 13TH.

"Modern Gas Lighting" by S. B. Stewart, Contract Agent for Consolidated Gas Company, Pittsburgh, Pa. This meeting will be devoted to the discussion of gas arcs as applied to modern illuminating systems. A number of prominent manufacturers and operators will be present and take part in the discussion.

APRIL 17TH.

"The Development of Flame Carbon Arc Lamps" by C. E. Stephens, Westinghouse Electric & Mfg. Company. The author will trace the growth and development of this popular form of illuminant from its inception down to the present time, showing how the difficulties first experienced have been overcome, and its application to various fields.

New Members.

At a meeting of the Council held December 12, 1913, the following 28 applicants were elected members of the society:

ANDERSON, C. E.
Educational Department, General Electric Company, Harrison, N. J.

ARBOGAST, O. J.
Salesman, Commonwealth Edison Company, 120 West Adams Street, Chicago, Ill.

BARNITZ, FRANK R.
Assistant Secretary, Consolidated Gas Company, 124 East 15th Street, New York City.

BERTSCHE, FRED.
Commonwealth Edison Company, 120 West Adams Street, Chicago, Ill.

BREUGGEMEYER, A. H.
Lighting Solicitor, Commonwealth Edison Company, 120 West Adams Street, Chicago, Ill.

CROWLEY, FRANK M.
Lighting Salesman, Commonwealth Edison Company, 120 West Adams Street, Chicago, Ill.

DAWSON, JAMES.
Salesman, Commonwealth Edison Company, 120 West Adams Street, Chicago, Ill.

DONNELLY, JAS. E.
Light Salesman, Commonwealth Edison Company, 120 West Adams Street, Chicago, Ill.

GRINER, CHARLES A.
Salesman, Commonwealth Edison Company, 120 West Adams Street, Chicago, Ill.

HECKER, L. M.
Salesman, Contract Department, Commonwealth Edison Company, 120 West Adams Street, Chicago, Ill.

HORAN, WILLIAM H.
Salesman, Commonwealth Edison Company, 120 West Adams Street, Chicago, Ill.

HYEDAHL, NICK.
Commonwealth Edison Company, 120 West Adams Street, Chicago, Ill.

KAEDER, F. J.
Salesman, Commonwealth Edison Company, 120 West Adams Street, Chicago, Ill.

KEYS, HARVEY A.
Light Salesman, Commonwealth Edison Company, 120 West Adams Street, Chicago, Ill.

LANCASTER, WALTER B.
Physician, 101 Newbury Street, Boston, Mass.

LONG, CLAUDE P.
Solicitor, Contract Dept., Commonwealth Edison Company, 120 West Adams Street, Chicago, Ill.

LORENZ, J. M.
Salesman, Central Electric Company, 320 5th Avenue, Chicago, Ill.

MYERS, ROMAINE W.
Consulting Engineer, 204 Bacon Building, Oakland, Cal.

O'BRIEN, JOHN C.
Lighting Salesman, Commonwealth Edison Company, 120 West Adams Street, Chicago, Ill.

PECK, EDWARD L.
Inspector, Electrical Testing Laboratories, 80th Street and East End Avenue, New York City.

PRABEL, FREDERICK C.
Lighting Salesman, Commonwealth Edison Company, 120 West Adams Street, Chicago, Ill.

REILL, WILFRED J.
Lighting Salesman, Commonwealth Edison Company, 120 West Adams Street, Chicago, Ill.

REINACH, HUGO B.
Asst. Gen'l. Superintendent, Consolidated Gas Company, 124 East 15th Street, New York City.

ROSENBERG, MAURICE.
General Manager, Shapiro & Aronson, 20 Warren Street, New York City.

RUSCH, WILLIAM T.
Assistant to Engineer of Utilization, Consolidated Gas Company, 124 East 15th Street, New York City.

SEVERN, GEORGE K.
Salesman, Commonwealth Edison Company, 120 West Adams Street, Chicago, Ill.

STILWELL, JOHN.
Efficiency Engineer, Consolidated Gas Company, 124 East 15th Street, New York City.

WINANS, R. K.
Lighting Agent, Commonwealth Edison Company, 120 West Adams Street, Chicago, Ill.

Additional Sustaining Members.

The following five companies were elected sustaining members of the society, December 12, 1913:

CONSOLIDATED GAS COMPANY OF NEW YORK.
124 East 15th Street, New York City.

NATIONAL X-RAY REFLECTOR COMPANY.
235 West Jackson Boulevard, Chicago, Ill.
Official Representative: Augustus D. Curtis.

PUBLIC SERVICE COMPANY OF NORTHERN ILLINOIS.
157 South LaSalle Street, Chicago, Ill.

STONE & WEBSTER.
147 Milk Street, Boston, Mass.

THE CLEVELAND ELECTRIC ILLUMINATING COMPANY.
Cleveland, Ohio.
Official Representative: R. H. Wright.

International Electrical Congress.

The International *Electrical* Congress is to be held at San Francisco, September 13 to 18, 1915, under the auspices of the American Institute of Electrical Engineers by authority of the International Electrotechnical Commission, and during the Panama-Pacific International Exposition. Dr. C. P. Steinmetz has accepted the honorary presidency of the Congress. The deliberations of the Congress will be divided among twelve sections which will deal exclusively with electricity and electrical practise. There will probably be about 250 papers. The first membership invitations will be issued in February or March, 1914.

Attention is drawn to the distinction between this Electrical Congress and the International *Engineering* Congress which will be held at San Francisco during the week immediately following the Electrical Congress. The Engineering Congress is supported by the Societies of Civil, Mechanical and Marine Engineers and by the Institutes of Mining and Electrical Engineers, as well as by prominent Pacific Coast engineers who are actively engaged in organizing it. This Congress will deal with engineering in a general sense, electrical engineering subjects being limited to one of the eleven sections which will include about twelve papers, treating more particularly applications of electricity in engineering work.

The meeting of the International Electrotechnical Commission will be held during the week preceding that of the Electrical Congress.

Nomenclature.

At the next meeting of the Committee on Nomenclature and Standards, which will take place in February, the following definitions will come up for discussion:

A *direct lighting system* is one in which substantially all the useful light flux comes directly from the illuminant, including its diffusing or reflecting auxiliaries.

An *indirect lighting system* is one in which substantially all the useful light flux is received by diffuse reflection from the ceiling, walls or other diffusely reflecting surfaces of relatively large extent.

Criticisms and comments on these definitions may be sent to the secretary of the committee, Dr. Clayton H. Sharp, 80th Street and East End Avenue, New York, N. Y.

FINANCIAL REPORT FOR FISCAL YEAR ENDING SEPTEMBER 30, 1913.

WM. J. STRUSS & Co.
Certified Public Accountants
93-99 Nassau Street
New York

October 24th, 1913.

MR. WILLIAM CULLEN MORRIS.
Chairman, *Finance Committee*,
Illuminating Engineering Society,
29 West 39th Street,
New York, N. Y.

Dear Sir:—

In accordance with your instructions we have examined the books and accounts of the Illuminating Engineering Society for the nine (9) months ended September 30th, 1913.

The results of this examination are set forth in the two exhibits, attached hereto, as follows:

Exhibit "A"—Balance Sheet, September 30th, 1913.
Exhibit "B"—Earnings and Expenses, for the nine months ended September 30th, 1913.

We hereby certify that the accompanying Balance Sheet is a true exhibit of its financial condition as of September 30th, 1913, and that the attached statement of Earnings and Expenses is correct.

Respectfully submitted,
WM. J. STRUSS & Co.,
Certified Public Accountants.

ILLUMINATING ENGINEERING SOCIETY BALANCE SHEET
SEPTEMBER 30TH, 1913.
EXHIBIT "A"

Assets

Cash on hand and in bank		$2,443.53
Accounts receivable—		
1912 Miscellaneous	$ 20.28	
1913 Miscellaneous	279.40	
1913 Dues	430.00	
1913 Initiation fees	120.00	
1913 Advertising	4.46	
1914 Dues	120.00	
1914 Dues—sustaining members	675.00	
		1,649.14

Investments—		
Northern Pacific & Great Northern Railway Bonds—$2,000.00 (book value)		1,920.00
Furniture and fixtures	894.71	
Less depreciation 15 per cent	134.20	760.51
Badges on hand		45.00
Accrued interest on bonds		20.00
		$6.838.18

Liabilities.

Advanced and unearned items—		
Advance Dues, 1913	$ 250.00	
Fees, 1913	35.00	
Advertising, 1913	4.93	
Dues, 1914	160.00	
Fees, 1914	20.00	
Dues sustaining members 1914	60.00	
Unearned Sustaining members dues	935.42	
Dues	1,717.50	3,182.85
Outstanding debts (estimated)		1,789.93
Surplus Balance, January 2, 1913	1,453.94	
Back dues collected 1912	73.00	
Convention fund surplus 1912	177.74	
Miscellaneous	79.88	
Net gain for the nine months, ended September 30, 1913, as per Exhibit "B"	80.84	1,865.40
		$6,838.18

ILLUMINATING ENGINEERING SOCIETY

STATEMENT OF EARNINGS AND EXPENSES FOR THE NINE MONTHS ENDED SEPTEMBER 30TH, 1913.

EXHIBIT "B"

Earnings.

Members dues	$5,207.50	
Initiation fees	360.00	
Advertising	1,097.14	
Profit on badges sold	6.50	
Certificates	1.70	
Interest on bonds	60.00	
Miscellaneous sales of TRANSACTIONS	211.52	
Illumination Primer	616.25	
Sustaining members dues	689.58	
Annual meeting	6.30	
		$8,256.49

Expenses.

TRANSACTIONS		$1,844.72	
General office—			
Salaries	$2,226.14		
Rent	633.15		
Postage	236.35		
Telephone and telegraph	143.96		
Printing and stationery	294.24		
Miscellaneous	235.00	3,768.84	
New York Section		245.03	
Chicago Section		217.04	
New England Section		53.78	
Pittsburgh Section		149.73	
Philadelphia Section		130.88	
1913 Convention		257.67	
1913 Election expense		57.44	
Committee on—			
Nomenclature and Standards		14.67	
Glare		60.00	
Research		17.50	
Popular Lectures		4.25	
Collegiate Education		10.75	
Papers		14.35	
Sustaining Membership		6.40	
Joint meetings with other societies		43.57	
Depreciation on furniture and fixtures		134.20	
Miscellaneous expense		100.65	
Advance copies and reprints		9.93	
Exchange and discount		9.25	
Unpaid accounts (estimated)—			
General office	30.00		
Transactions	5.00		
Miscellaneous	75.00		
1913 Convention	915.00	1,025.00	8,175.65
Excess of earnings over expenses			$ 80.84

TRANSACTIONS

OF THE

Illuminating Engineering Society

DECEMBER, 1913

PART II

Papers, Discussions and Reports

[DECEMBER, 1913]

CONTENTS -- PART II

THE LIGHTING OF SHOW WINDOWS.*

BY H. B. WHEELER.

Synopsis: The lighting of a number of typical show windows is discussed with respect to the intensity required along the line of trim, and the selection of reflectors, their spacings and methods of installation. Illustrations, plans and illuminometer readings and curves of a number of well lighted windows are given. The material is arranged so as to make the selection, spacing, and installation of reflectors very simple. The paper is divided into two sections: The first covers methods of illuminating various typical windows. The second gives test data on the same.

Up to the present time very little data has been presented on the lighting of show windows. That which has been given pertains chiefly to the requirements of good show window lighting, the influence of surroundings on the treatment of a window and, occasionally, a description of some one notable installation. I have assumed that the foregoing matters are well established facts, and therefore this paper is devoted to methods of obtaining these good results in window illumination.

Typical show windows have been grouped in three classes which for convenience are designated as A, B and C; and the more special windows in two other classes, referred to as D and E. For each class I show a window of the type under consideration, the reflector which was used, the method of installing the reflector, and a distribution curve of the reflector.

The questions of selecting the proper reflector for a window, and the spacings to be used, to give the desired intensity of illumination along the line of trim, are discussed, and I have added recommendations of the intensities I have found good practise for show windows. Lamps, shade holders, window drapes (valances), and other features of window trimming that are of vital interest to the illuminating engineer are discussed briefly. The paper also includes the results of tests made on typical windows of the various classes discussed.

* A paper read at the seventh annual convention of the Illuminating Engineering Society, Pittsburgh, Pa., September 22-26, 1913.

In general there are two types of windows: (1) open back; (2) boxed-in. In the first class the display is usually very low, in most cases being practically horizontal. The problem here is merely to provide the proper intensity of horizontal illumination. Since these windows are generally quite shallow and high, they require a concentrating type of reflector for the very shallow window, and a semi-concentrating for the deeper ones.

The reflectors shown in Figs. 10 and 7, Nos. 755 and 780, respectively, are most suitable for such windows.

The following classification I believe takes into account all of the various types of boxed-in windows encountered to-day.

TYPICAL WINDOWS.

Class A Windows: Height equal to depth. High trim. Average height 9 ft. (2.74 m.). Depth 9 ft. (2.74 m.). Height of trim 9 ft. (2.74 m.).

Class B Windows: (1) Height 1½ times depth. Medium trim. Average height 10 ft. (3.04 m.). Depth 6 ft. (1.83 m.). Height of trim 7 ft. (2.13 m.).

(2) Height 1½ times depth. High trim. Average height 10 ft. (3.04 m.). Depth 6 ft. (1.183 m.). Height of trim 9 ft. (2.74 m.)

Class C Windows: Height 2 times depth. Medium trim. Average height 12 ft. (3.65 m.). Depth 6 ft. (1.83 m.). Height of trim 7 ft. (2.13 m.).

SPECIAL WINDOWS.

Class D Windows: Height equal to depth. High trim. Average height 5 ft. (1.52 m.). Depth 6 ft. (1.83 m.). Height of trim 5 ft. (1.52 m.).

Class E Windows: Height 2 times depth. Low trim. Average height 5 ft. (1.52 m.). Depth 2 ft. 6 in. (0.76 m.). Height of trim 2 ft. (0.61 m.).

The height of the window is always measured from the floor to the ceiling; the depth, from the glass front to the back; the trim, from the floor up.

Class A Windows.—In Fig. 1 is shown a Class A window.

Windows of this class usually are trimmed up high on the background, and hence require a reflector which distributes the light flux over the angle zero to 90 degrees.

The reflector shown in Fig. 2 has been designed to meet this condition; its distribution curve is shown in Fig. 4. This reflector is a non-symmetrical reflector, with a portion of the front cut away, to permit the light flux to escape horizontally. Hence a large portion of the lamp is exposed to view from within the window. Mirrors should not be placed in the upper part of the background, in order to avoid the possibility of seeing an image of the lamp when observing the window from the street.

The practise of using mirrors in any window should be discouraged as images of surrounding objects are generally present, which detract from the goods on display. One of the chief reasons why merchants desire mirrors, is the fact that they believe the observer will be enabled to see both the front and back of the objects in the window. However, the brightness to which the back of the objects is illuminated is so low that the results are not very satisfactory. In addition to this, much brighter images of surrounding objects serve to detract rather than add to the effect sought.

Fig. 1.—A Class A window; height 9 ft., depth 9 ft., equipped with 60-watt clear tungsten lamps in reflectors (Fig. 2) on 15-inch centers.

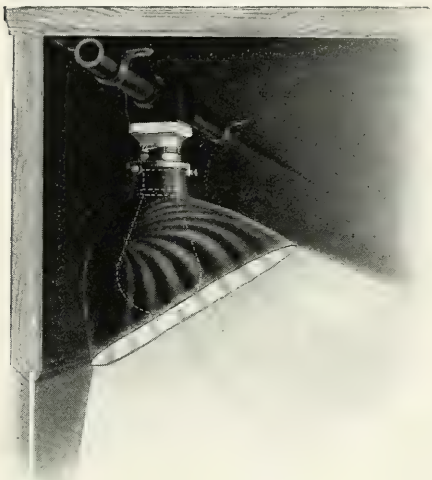


Fig. 2.—Reflector (No. 777). Details for installing in windows shown in Fig. 3.

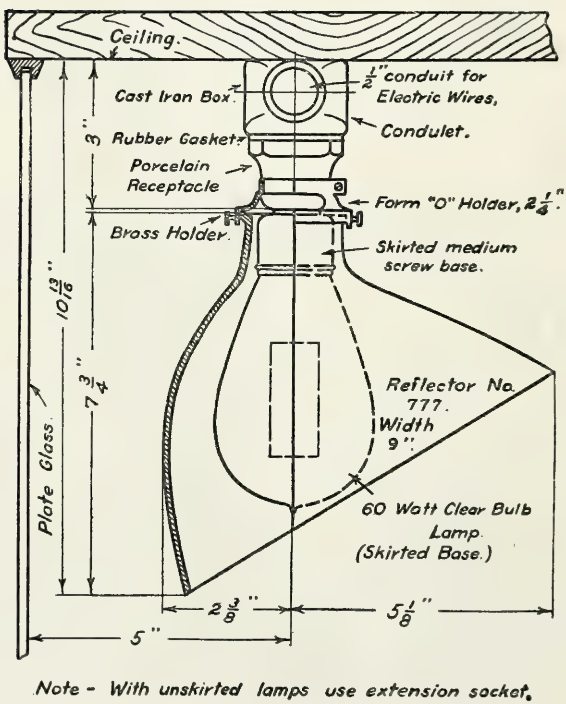
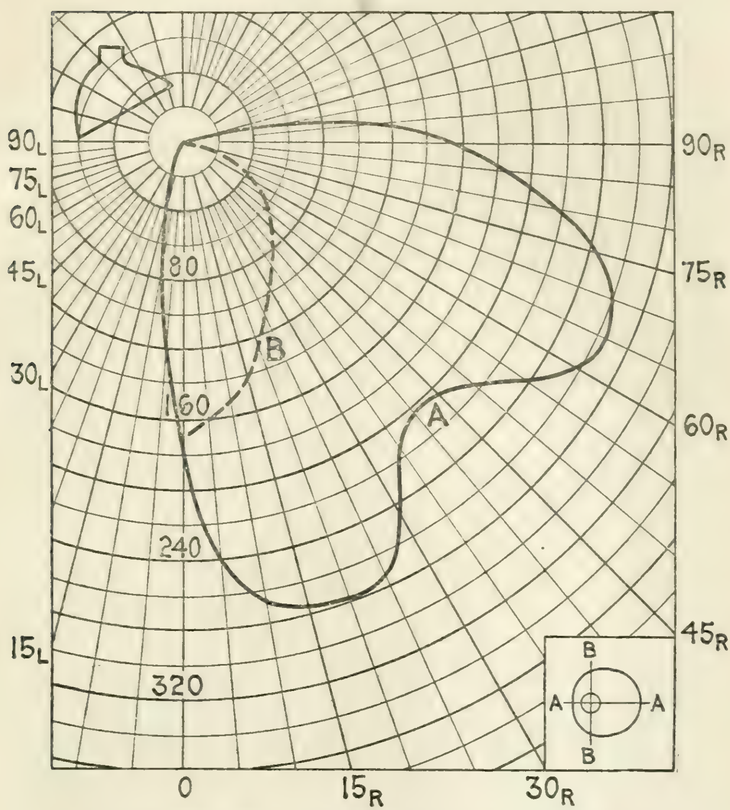


Fig. 3.—Details for installing in windows reflector shown in Fig. 2.



ANGLE	CANDLE POWER			ANGLE	CANDLE POWER		
	CURVE A		CURVE B		CURVE A		CURVE B
	R	L	R		R	L	R
0	166.3	166.3	166.3	90	151.6		
5	255.2	1109	159.5	95	110.2		
15	272.4	38.5	142.5	105	25.7		
25	281.0	19.9	112.7	115	1.2		
35	211.9	6.8	84.2	125			
40				135			
45	204.9		71.7	145			
55	239.7		58.2	155			
65	265.6		39.6	165			
75	249.3		19.7	175			
85	191.8		3.4	180			

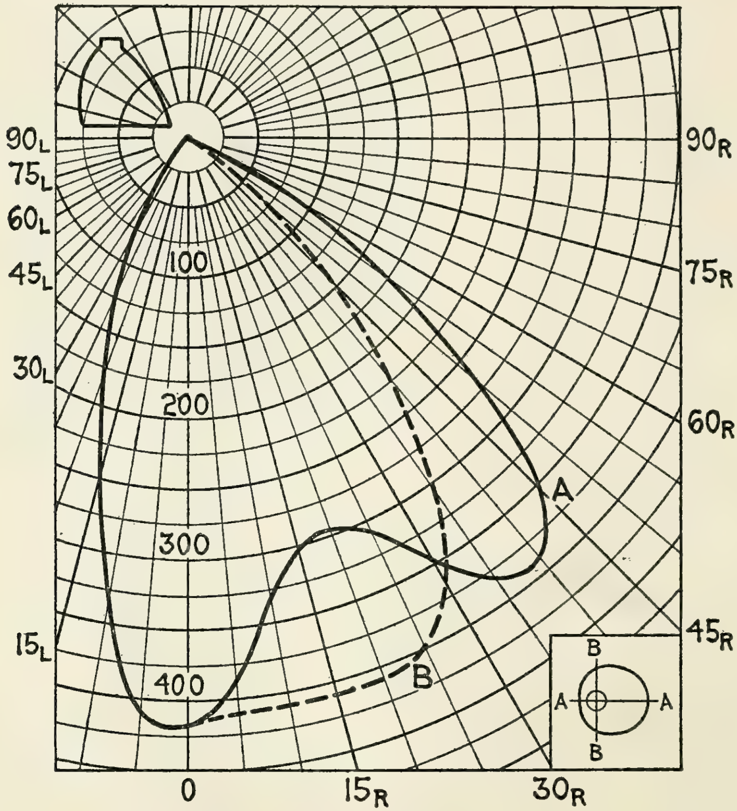
REFLECTOR *No 777*

HOLDER *2¼" Form "O"*

LAMP *Clear Tungsten S-24½-A*

WATTS *63.6* VOLTS *115.8*

Fig. 4.—Photometric distribution curve and data on reflector No. 777, shown in Fig. 2, with 1.25-watt-per-candle tungsten lamp.



ANGLE	CANDLE POWER CURVE A R	CANDLE POWER CURVE A L	CANDLE POWER CURVE B R	ANGLE	CANDLE POWER CURVE A R	CANDLE POWER CURVE A L	CANDLE POWER CURVE B R
0	415.0	415.0	415.0	90			
5	388.0	411.0	408.0	95			
15	301.0	247.0	408.0	105			
25	307.0	116.0	400.0	115			
35	380.0	22.0	297.0	125			
40				135			
45	353.0	4.2	137.0	145			
55	156.0		24.6	155			
65	20.5		3.1	165			
75	2.4			175			
85				185			

REFLECTOR No. 780

HOLDER 3¼" Form "A"

LAMP Clear Tungsten S-30-A

WATTS 100.0 VOLTS. 110.0

Fig. 5.—Photometric distribution curve and data on reflector (No. 780) shown in Fig. 7, with 1.08-watt-per-candle clear tungsten lamp.

Class B Windows.—In Fig. 6 is shown a Class B window. The more common windows of this class are trimmed only to a medium height, but occasionally some are found in which the trim is carried up high. The first sub-division requires the use of a reflector which distributes the light flux in the angle zero to 55 degrees.

The reflector shown in Fig. 7 has been designed to accomplish this result. Its distribution curve is shown in Fig. 5.

Reflector No. 780 not only confines the light flux where desired, but hides the lamp filament from view within the store, with even a medium height background. Curtains above the background are often used to conceal the reflectors. (see Fig. 6.)

For the second sub-division it is necessary to use a combination of the reflectors shown in Figs. 2 and 7 in order to get the desired results.

A solid background is advisable with this latter arrangement unless suitable curtains are used.

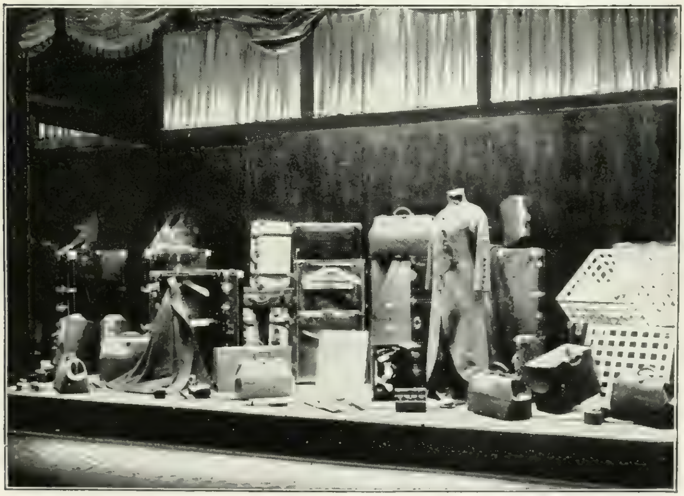


Fig. 6.—A Class B window; height 12 ft., depth 7 ft., background 8 ft., equipped with clear 100-watt tungsten lamps in reflectors (Fig. 7) on 12-inch centers.

Fig. 7.—Reflector (No. 780). Details for installing in windows shown in Fig. 8.

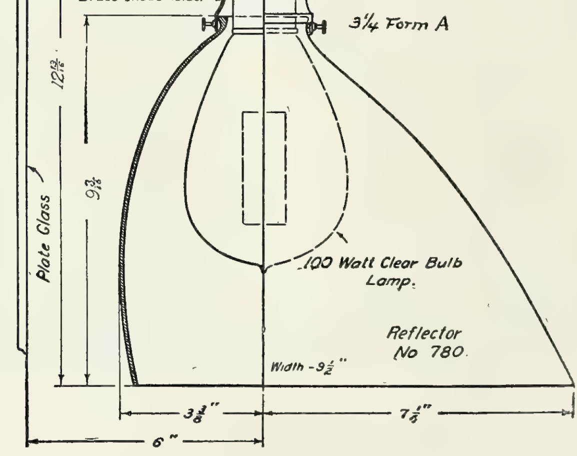


Fig. 8.—Details for installing in windows reflector (No. 780) shown in Fig. 7.

Class C Windows.—In Fig. 9 is shown a Class C window. In this class of window the trim is carried up to only a medium height. A reflector which concentrates the light flux in the angle intercepted by the line of trim, most nearly meets the conditions. This angle is relatively smaller than for most other types of windows, and hence presents a much harder problem to be dealt with. It is not only necessary to get high concentration on the floor of the window, but the background also must be properly illuminated to the top of the trim, and the light flux cut-off quite sharply at this point.

Fig. 10 shows a reflector which has been designed to give the required results. Its light distribution curve is shown in Fig. 12

Fig. 9.—A Class C window, height 16 ft. 6 in., depth 8 ft., background 8 ft., equipped with 100-watt clear tungsten lamps in reflectors (Fig. 10) on 18-inch centers.

Fig. 10.—Reflector (No. 755) details for installing in windows shown in Fig. 11.

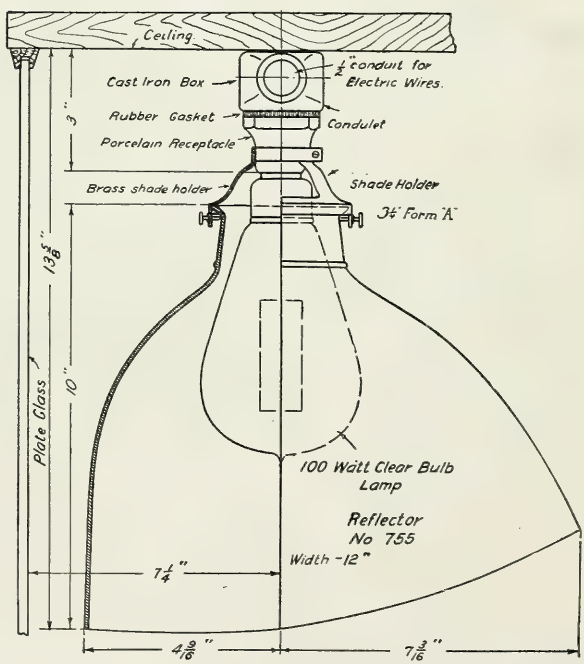
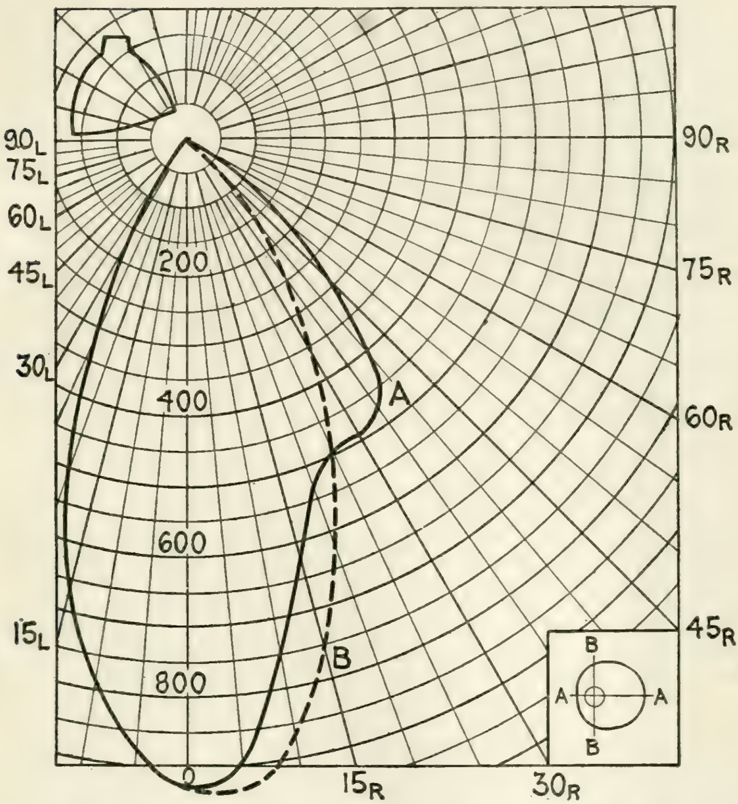


Fig. 11.—Details for installing in windows reflector (No. 755) shown in Fig. 10.



ANGLE	CANDLE POWER Curve A R	CANDLE POWER Curve A L	CANDLE POWER Curve B R	ANGLE	CANDLE POWER Curve A R	CANDLE POWER Curve A L	CANDLE POWER Curve B R
0	926.0	926.0	926.0	90			
5	895.0	877.0	932.0	95			
15	617.0	665.0	757.0	105			
25	497.0	214.0	488.0	115			
35	472.0	70.0	230.0	125			
40				135			
45	280.0	8.6	81.8	145			
55	112.0	2.0	16.6	155			
65	13.8		7.2	165			
75	2.7		3.1	175			
85				180			

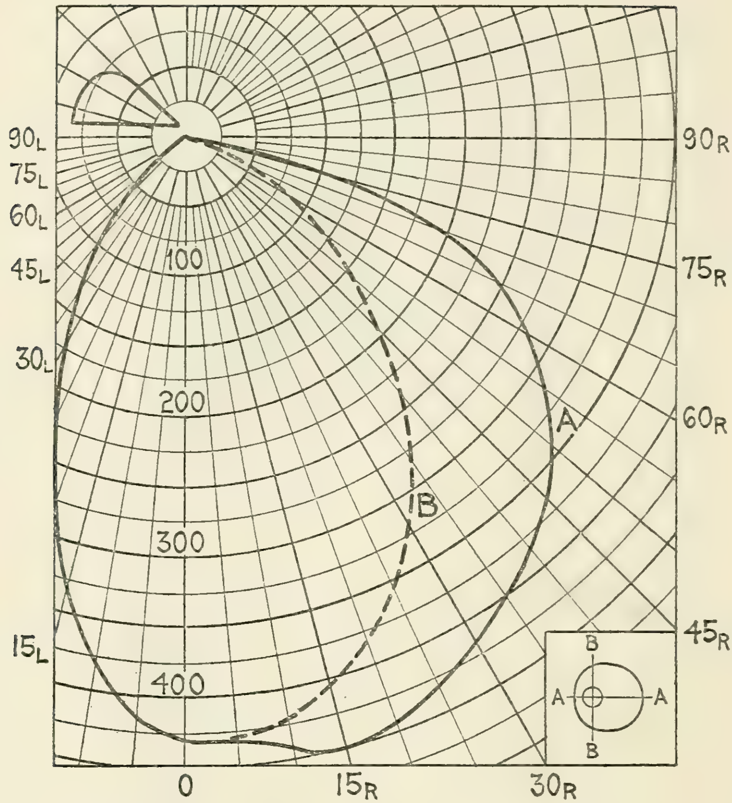
REFLECTOR *No. 755*

HOLDER *$3\frac{1}{4}$" Form "A"*

LAMP *Tungsten S-30-A-Clear*

WATTS *100.0* VOLTS *110.0*

Fig. 12.—Photometric distribution curve and data on reflector (No. 755) shown in Fig. 10, with a 1.08-watt-per-candle lamp.



ANGLE	CANDLE-POWER			ANGLE	CANDLE POWER		
	CURVE A		CURVE B		CURVE A		CURVE B
	R	L	R		R	L	R
0	428.0	428.0	428.0	90			
5	432.0	413.0	428.0	95			
15	448.0	330.0	404.0	105			
25	430.0	223.0	354.0	115			
35	401.0	131.0	282.0	125			
40				135			
45	366.0	61.2	196.0	145			
55	314.0	24.0	116.0	155			
65	244.0		62.0	165			
75	96.6		36.5	175			
85	12.1		15.7	180			

REFLECTOR *No. 750*

HOLDER *Special attached*

LAMP *Clear Tungsten S-21-E*

WATTS *120.0* VOLTS *110.0*

Fig. 13.—Photometric distribution curve and data on reflector (No. 750) shown in Fig. 15, with 1.12-watt-per-candle clear tungsten lamp.

Class D Windows.—This class of window is found chiefly in cases where the show window is divided into two tiers, and in shops with low head room, situated on the ground floor. The light distribution required is essentially that of the reflector shown in Fig. 2, but there is not sufficient head room in these windows to permit its use.

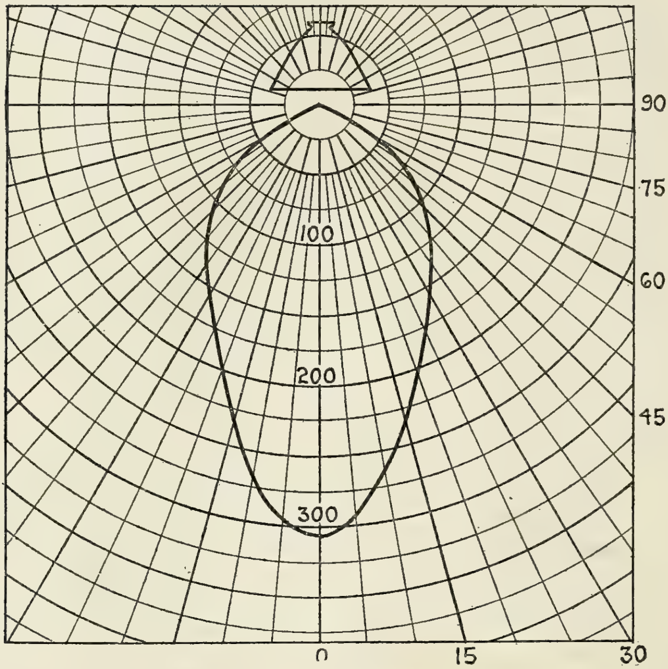
Fig. 15 shows a reflector which has been designed to meet the latter condition. Its light distribution curve is shown in Fig. 13. This reflector is provided with an adjustable holder as shown in Fig. 16, and the lamps are placed horizontally in the reflector. It is usually installed with the flat side tilted at an angle of approximately 15 degrees with the horizontal. A mirror background should not be used in a window of this type for obvious reasons.

Class E Windows.—In Fig. 18 is shown a class E window. This class of window is found largely in jewelry stores, cigar stores, and shoe stores. The line of trim is low, and frequently it is practically flat. This window requires a reflector having a light distribution curve similar to that of the reflector shown in Fig. 10. This reflector of course is too large for a window of this size.

The reflector (Fig. 19) installed as shown in Fig. 20, has been largely used for this type of window. Its distribution curve is shown in Fig. 14. A window may be illuminated in this manner very satisfactorily, but since the reflector is symmetrical it is not so economical, inasmuch as a great deal of the light flux escapes to the street and upper portion of the window. The percentage of the total light flux incident on the surface of the line of trim is low.

At the present time a small non-symmetrical reflector like that shown in Fig. 10 is being developed for this class of windows.

Preliminary tests on this new reflector with an unskirted base 60-watt clear bulb tungsten lamp show a highly concentrated light distribution very similar to that of Fig. 12. The cut-off at the window side of the reflector is slightly sharper than for the No. 755 reflector.



ANGLE	CANDLE POWER		ANGLE	CANDLE POWER	
	LAMP & REFL.	BARE LAMP		LAMP & REFL.	BARE LAMP
0	306.0		90		
5	295.0		95		
15	234.0		105		
25	175.0		115		
35	140.0		125		
40			135		
45	108.0		145		
55	66.6		155		
65	19.0		165		
75			175		
85			180		

	LAMP AND REFLECTOR			BARE LAMP		
ZONE • •	0-60	0-90	0-180	0-60	0-90	0-180
LUMENS	406.9	425.7	425.7			525.0

REFLECTOR No. 695 HOLDER 2¼" Form "O"

LAMP Tungsten WATTS 60.0 VOLTS 110.0

Fig. 14.—Photometric distribution curve and data on reflector shown in Fig. 19, with a 1.12-watt-per-candle lamp.

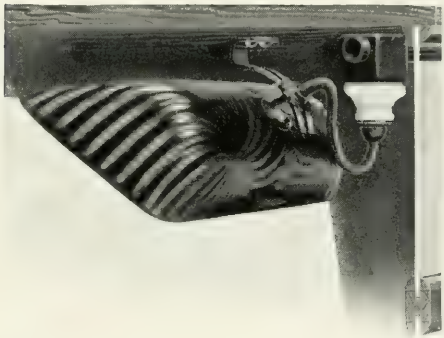


Fig. 15.—Reflector (No. 750). Details for installing in window shown in Fig. 16.

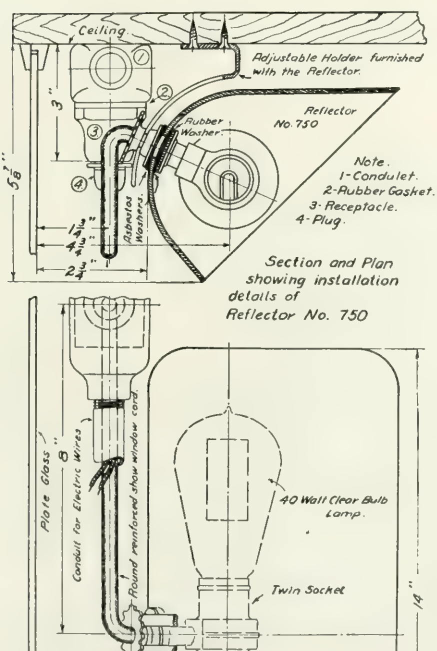


Fig. 16.—Details for installing in windows reflector (No. 750) shown in Fig. 15.

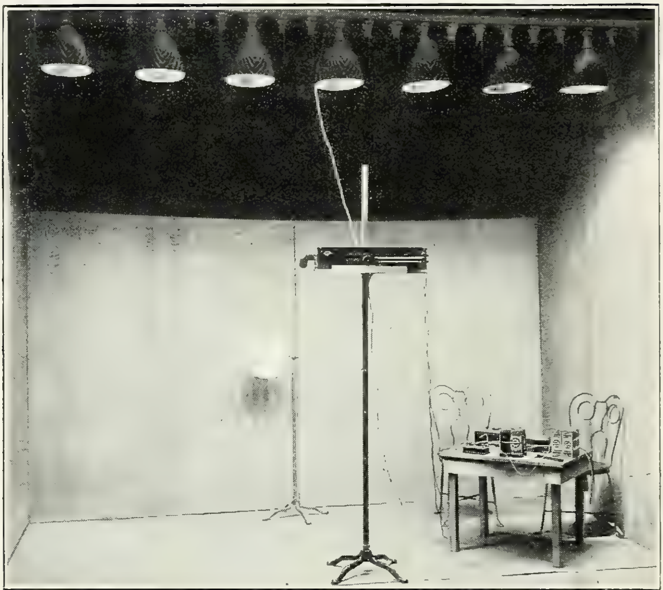


Fig. 17.—Test window set up as a Class B window.

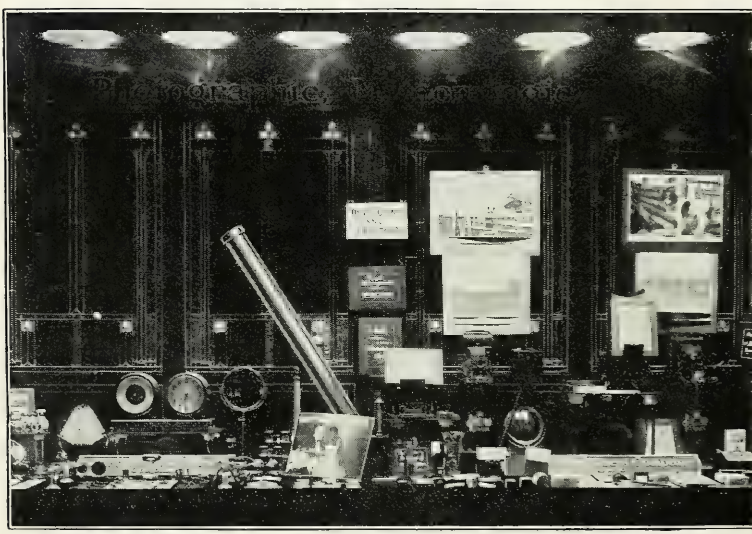


Fig. 18.—A Class E window; height 5 ft., 3 in., depth 3 ft., equipped with 60-watt clear tungsten lamps in reflectors (Fig. 19) on 15-inch centers.

Fig. 19.—Reflector (No. 696). Details for installing in windows shown in Fig. 20.

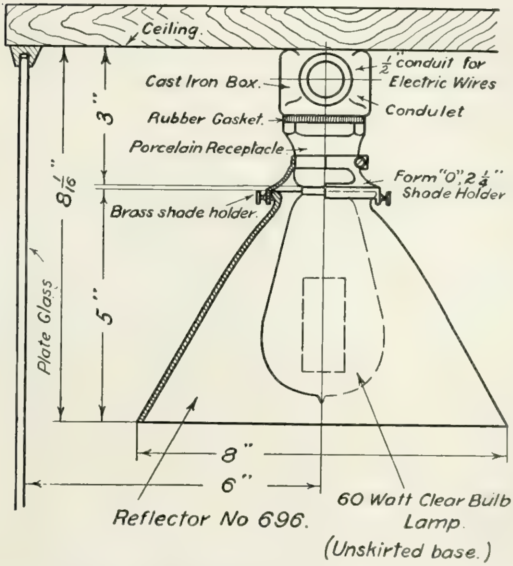


Fig. 20.—Details for installing in windows reflector (No. 696) shown in Fig. 19.

Fig. 21.—Show window drape (valance).

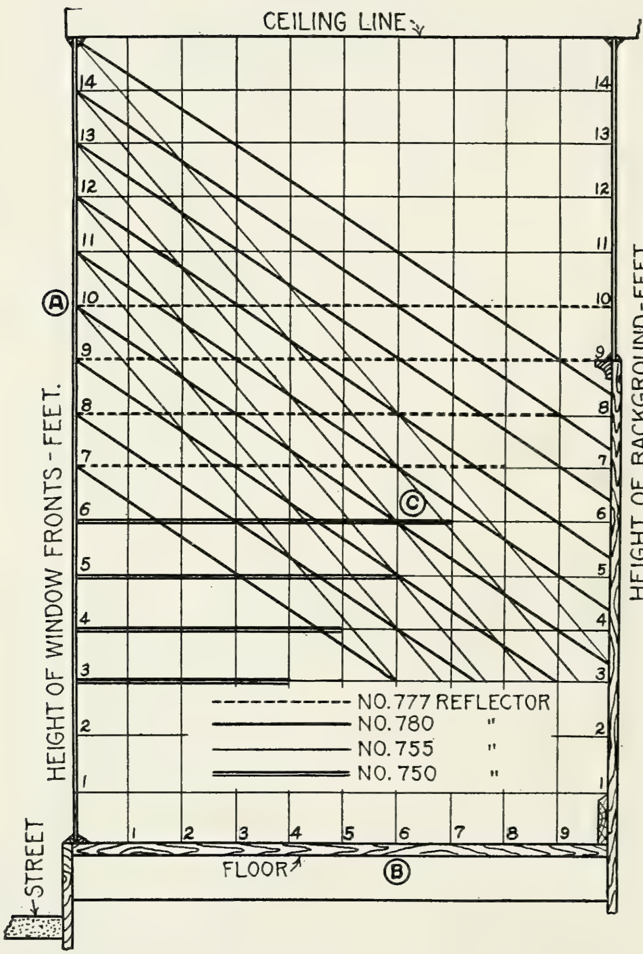


Fig. 22.—Chart for the selection of the proper reflector.

SELECTION OF REFLECTORS.

The chart shown in Fig. 22 makes easy the selection of the correct reflector for any type of window. To start with, knowledge of three things is necessary: height, depth of window, and height of trim at background.

Suppose, for example, the show window is 10 ft. (3.04 m.) high, 6 ft. (1.83 m.) deep and the trim or background to be lighted is 6 ft. (1.83 m.) high. The procedure would be as follows:

First, find the height of the window (10 ft.) on the left-hand vertical scale. This point is indicated at "A."

Second, locate depth of window (6 ft.) on lower horizontal scale. This point is indicated at "B."

Third, straight up from the latter point locate another point corresponding to the highest point to which the window is trimmed (in this case 6 ft.). This point is indicated at "C."

Next note the diagonal line that most nearly passes through the two points, "A" and "C" (which in this case is a heavy dark line). By referring to the key below one finds the reflector designated by the heavy dark line ——————— is reflector No. 780, which is the correct reflector for this window. In the above example, if the window were 12 ft. high, the chart would call for reflector No. 755. This chart is based on the use of the lamp for which each reflector herein mentioned is designed.

Where it is necessary to place reflectors on the transom bar, they may be selected by using the distance from the floor of the window to the bar as the height of ceiling.

SPACING OF REFLECTORS.*

For Class A-B-C windows the spacing, or distance from center to center for the respective reflectors, is about as follows:

* For Class D and E see tables 7 and 8 respectively for average conditions.

TABLE I.—REFLECTOR SPACINGS.

Population of town or city	Reflector	Spacing	Size of lamp watts	Average foot-candles along line of trim
10,000 and under	No. 777 (Fig. 2)	28 in.	60	10
	No. 780 (Fig. 7)	36 in.	100	10
	No. 755 (Fig. 10)	48 in.	100	10
10,000-30,000	No. 777 (Fig. 2)	18 in.	60	15
	No. 780 (Fig. 7)	24 in.	100	15
	No. 755 (Fig. 10)	36 in	100	15
30,000 and up	No. 777 (Fig. 2)	10 in.	60	30
	No. 780 (Fig. 7)	12 in.	100	30
	No. 755 (Fig. 10)	18 in.	100	30

The above table gives average illumination intensities found good practise in the live business centers of a town. For stores on the outskirts and in the outlying districts, reduced intensities will often be ample. Also due allowance must be made when the interior finish and trim is darker or lighter than the light oak for which the table has been compiled.

LAMPS.

The window reflectors discussed in this paper are designed exclusively for use with the standard tungsten lamps. Each reflector is designed for a certain size of lamp. All test data included in this paper is based on the use of the proper sizes of lamps for which the reflectors are designed.

REFLECTOR HOLDERS.

Owing to the fact that the many makes of shade holders differ materially in dimensions, I have found it essential to measure all known makes and determine which of these insure the proper position of lamp with respect to the reflector. It is quite essential that this position should be correct, if the best results are desired.

Fig. 23 shows a portion of a lamp, reflector, and holder. The values of dimensions F and G for the various reflectors are tabulated below, and the trade names of the shade holders having these dimensions are given.

If all shade holders were standardized it would be of infinite value to all concerned.

TABLE II.

Reflector	Holder position	F	G	Porcelain receptacles	Brass shell sockets
Fig. 2	Form "O"	2¼ ins.	1 in.	A-C	B-H-X-S-P
Fig. 7	" "H"	2¼ ins.	1 15/16 in.	A-C	B-H-P
Fig. 10	" "A"	3¼ ins.	1 15/16 in.	A	H
Fig. 19	" "O"	2¼ ins.	1 in.	A-C	B-H-X-S-P

Symbols used: A—Appleton; C—Crouse-Hinds; H—Holophane; B—Bryant; P—Plume & Atwood; X—Hubbel; S—P. & S.

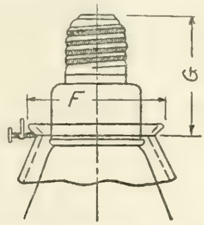


Fig. 23.—Diagram of reflector and lamp socket.

WINDOW DRAPES (VALANCES).

In order to conceal show window reflectors from the view of the observer on the street, window drapes or valances are very much used. In addition to performing the above functions, they add a touch of refinement and exclusiveness to a show window, greatly increasing the attractiveness of the merchandise displayed. Many attractive designs are now being manufactured for this use. Fig. 21 shows one type in which the firm's monogram is inscribed.

TEST METHODS AND DATA.

Test Windows.—Experimental windows for use in testing the illumination of Class A, B, C, D and E windows, were made from wood frames of various sizes, over which was stretched a heavy paper backed with cloth, in much the fashion of stage scenery. This paper was the color of natural light oak. By using various combinations of the frames at hand, the typical windows were readily constructed. For the floors the same type of paper in a darker oak was used.

Fig. 17 shows the test window set up as a class B window, with reflectors like that of Fig. 7 in place. From the illustration it will be noted that the reflectors and lamps are supported from the 2 in. x 4 in. (5.08 cm. x 10.16 cm.) strip, which was supported

from two standards having raising and lowering features. Pull sockets on 6-inch (15.24 cm.) centers the entire length of the wood strip, made it possible to obtain the various reflector spacings desired.

A black curtain was hung at the front of the window in the position of the glass in an actual window. In windows having a medium height of trim in which the upper portion of the background is glass, as for instance Class B, a black curtain was hung in this position. The black cloth which reflects a negligible amount of light flux, was considered a good substitution for clear glass. Whatever slight difference this substitution may make, I feel it is of small moment and that the results obtained are representative of the various classes of windows tested.

The line of trim for the various classes of windows was chosen for the condition I found existing in the majority of windows.

Instruments.—The instruments used for this series of tests were a Sharp-Millar portable photometer with a standard lamp and detached test plate of white diffusing glass mounted on black velvet; a Weston milli-ammeter with shunt and shunt leads; and a Wagner A. C. or D. C. voltmeter. All instruments were carefully calibrated, both before and after tests. The mean horizontal candle-power and wattage of all lamps used, were determined before beginning the tests. The milli-ammeter was used to measure the current passing through the standard lamp. The volt meter was used to measure the voltage at the lamp terminals.

Method of Conducting Tests.—Tests of the normal illumination along the line of trim were made at the stations as indicated for each class of window in the subsequent figures. The location of the stations was accomplished by measuring the horizontal distances from front to rear of window, and marking the vertical distances on the adjustable standard used for supporting the detached test plate.

The photometer was placed in such a position that the line of sight of the instrument would be practically normal to the line of trim at each station. The reason for this was to facilitate placing the test plate parallel with the line of trim at any one station, since it was found that with a little practise the operator was able to locate by eye the test plate normal to the line of sight of the in-

strument. By experiment it was also found that it is not necessary to view the test plate normally. In fact readings when viewing the test plate at angles of 45 degrees either side of the normal, show but slight difference from the normal reading. Hence, readings of normal illumination along the line of trim taken with the photometer at the ordinary height of the eye, would not materially differ from those presented.

Readings of the voltage at the lamp terminals were made simultaneously with the illumination intensity readings.

In order to obtain some idea as to the relative co-efficient of reflection of the walls, ceiling and floor of the test windows, the following test was conducted:

The test plate used throughout the test, was set up in a given position, under the illumination from tungsten lamps, and the intensity of illumination incident thereon read.

The test plate was replaced by a disk of white blotting paper and another reading taken with the photometer. The white blotting paper was in turn replaced by a sample of the paper used on the walls and floor of the test window.

Assuming a reflection co-efficient of 100 per cent. for the test plate, the reflection co-efficient of the blotting paper and walls and floor of the test window, in terms of the white test plate was determined.

The values obtained are as follows:

1:	Test plate	100 per cent.
2:	Blotting paper	100 per cent.
3:	Walls of test window	58.4 per cent.
4:	Floor of test window	34.6 per cent.

Later the absolute co-efficient of reflection of the above blotting paper[1] was found to be 75 per cent.[2] From this it follows that the absolute co-efficient of reflection of the above surfaces are approximately (limited by the accuracy of the test) as follows:

	Per cent.
Test plate	75.0
Blotting paper (see Notes below)	75.0
Floor of test window	25.9
Walls of test window	43.8

[1] 140 Star.

[2] Determined by Mr. M. Luckiesh, of National Electric Lamp Association.

These values of course are not the absolute reflection co-efficients of the surfaces, but may be used comparatively, inasmuch as it is known that white blotting paper reflects about 75 to 82 per cent. light.

Method of Calculating Test Results.—In calculating the test results of illumination, foot-candle readings were corrected for 115 volts, the rated high voltage of the lamps used. These corrections were made in accordance with the lamp data supplied by the lamp manufacturer.

The effective lumens on the surface of the line of trim were calculated from the average of all the foot-candle readings taken in any one window. The actual wattage and mean horizontal candle-power of all lamps being known for 115 volts, the effective lumens per watt and the efficiency of utilization were calculated. This data is presented in the illumination tables for each class of window tested.

A floor plan and an elevation at one of the planes tested, is shown with the data on each of the windows. On the floor plan are indicated the location of the test planes and the location, number and spacing of the outlets. On the elevation are shown the line of trim, the test stations, and the reflector showing its position relative to the line of trim.

In addition to this a curve showing the normal illumination at the various test stations is given. The method of plotting this curve is rather peculiar, inasmuch as it is neither a polar nor a rectangular co-ordinate curve. The line of trim is indicated as the zero line of illumination intensity, and the various lines parallel to the line of trim are given foot-candle values as indicated. The length of the ordinate from the line of trim to the curve, represents the foot candle intensity of normal illumination at the station.

This curve drawn as it is, I believe is contrary to all precedent, and while it cannot be used for obtaining close approximations of the illumination intensity at points between stations, I believe it is a good method for giving one a graphical idea of the distribution of illumination intensity along the line of trim.

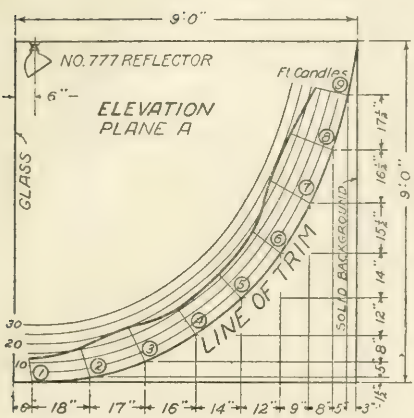


Fig. 24.—Elevation through Class A window showing uniformity of normal illumination along the line of trim.

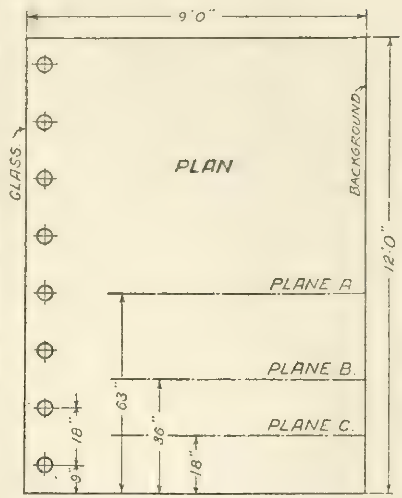


Fig. 25.—Plan of Class A window showing location of test planes and ceiling outlets.

TABLE 3.—SHOWING TEST RESULTS IN CLASS A WINDOW WITH REFLECTOR NO. 777 SHOWN IN FIG. 2.

Centers, 18 in.

Lamps, 60-watt, tungsten clear skirted.

Total watts, 501.9.

Number of units, 8.

Holder, 2¼ in. "O."

Watts per running foot, 41.82.

Plane	Station	Average foot-candles
A	1	12.4
	2	16.0
	3	19.2
	4	16.3
	5	17.7
	6	18.5
	7	23.7
	8	22.7
	9	17.4
B	1	10.0
	2	13.9
	3	16.6
B	4	12.3
	5	14.9
	6	17.1
	7	19.8
	8	19.3
	9	14.2
C	1	13.7
	2	16.3
	3	15.9
	4	13.4
	5	11.6
	6	12.2
	7	14.0
	8	13.8
	9	11.5

Average foot-candles, 15.75

Area of surface along line of trim. 168 sq. ft.

Effective lumens, 2650.

Effective lumens per watt, 5.27.

Total lumens of lamps alone, 4533.

Efficiency of utilization, 58.3 per cent.

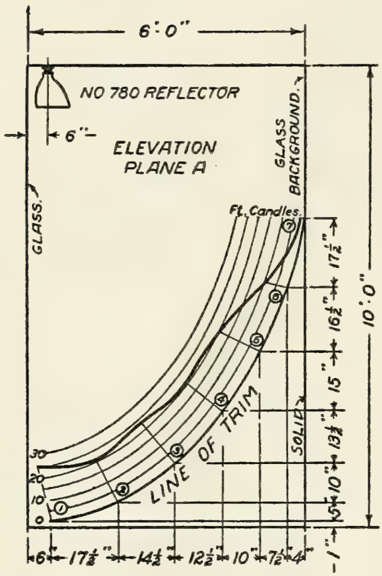


Fig. 26.—Elevation through Class B window (medium trim) showing uniformity of normal illumination along line of trim.

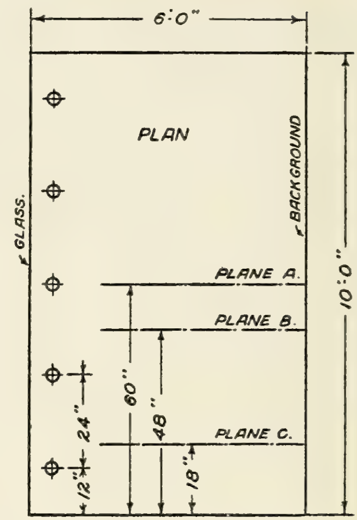


Fig. 27.—Plan of Class B window (medium trim,) showing location of test planes and ceiling outlets.

TABLE 4.—SHOWING TEST RESULTS IN CLASS B WINDOW (MEDIUM TRIM) WITH REFLECTOR NO. 780, SHOWN IN FIG. 7.

Centers, 24 in.
Lamps, 100-watt clear tungsten.
Total watts, 501.5.
Number of units, 5.
Holder, 3¼ in. "A."
Watts per running foot, 50.15.

Plane	Station	Average foot-candles
A	1	24.4
	2	21.7
	3	23.1
	4	21.3
	5	19.5
	6	10.0
	7	2.3
B	1	20.1
	2	21.7
	3	24.2
B	4	18.8
	5	22.3
	6	11.1
	7	2.8
C	1	17.8
	2	17.7
	3	17.0
	4	15.1
	5	15.2
	6	11.8
	7	3.0

Average foot-candles, 16.22.

Area of surface along line of trim, 95.0 sq. ft.

Effective lumens, 1540.

Effective lumens per watt, 3.08.

Total lumens of lamps alone, 4745.

Efficiency of utilization, 32.5 per cent.

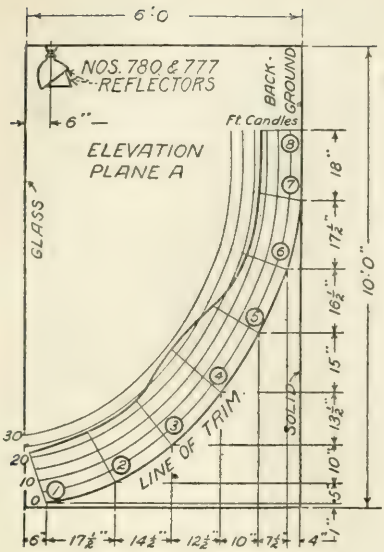


Fig. 28.—Elevation through Class B window (high trim) showing uniformity of normal illumination along the line of trim.

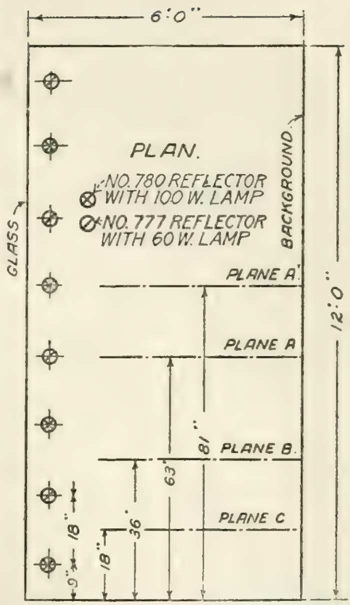


Fig. 29.—Plan of Class B window (high trim) showing location of test planes and ceiling outlets.

TABLE 5.—SHOWING TEST RESULTS IN CLASS B WINDOW (HIGH TRIM) WITH A COMBINATION OF REFLECTORS NOS. 780 AND 777 SHOWN IN FIGS. 7 AND 2 RESPECTIVELY.

Centers, 18 in.
Lamps, 4 100-watt clear tungsten skirted.
Lamps, 4 60-watt clear tungsten skirted.
Total watts, 653.55.
Number of units, 4 No. 780.
Number of units, 4 No. 777.
Holder, No. 780, 3¼ in. "A."
Holder, No. 777, 2¼ in. "O."
Watts per running foot, 54.46.

Plane	Station	Average foot-candles
A	1	21.9
	2	24.2
	3	22.6
	4	27.7
	5	22.5
	6	18.3
	7	18.3
	8	17.9
A1	1	20.5
	2	28.1
	3	24.8
	4	21.0
A1	5	20.3
	6	15.6
	7	16.5
	8	23.2
B	1	20.3
	2	22.9
	3	23.2
	4	21.0
	5	18.9
	6	16.3
	7	13.6
	8	14.8
C	1	19.10
	2	21.3
	3	22.1
	4	21.8
	5	21.4
	6	16.2
	7	15.1
	8	10.4

Average foot-candles, 20.23.
Area of surface along line of trim, 120.00.
Effective lumens, 2430.
Effective lumens per watt, 3.73.
Total lumens of lamps alone, 6023.
Efficiency of utilization, 40.3 per cent.

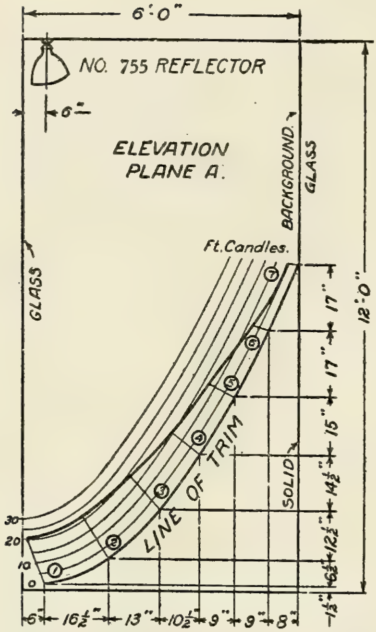


Fig. 30.—Elevation of Class C window showing uniformity of normal illumination along the line of trim.

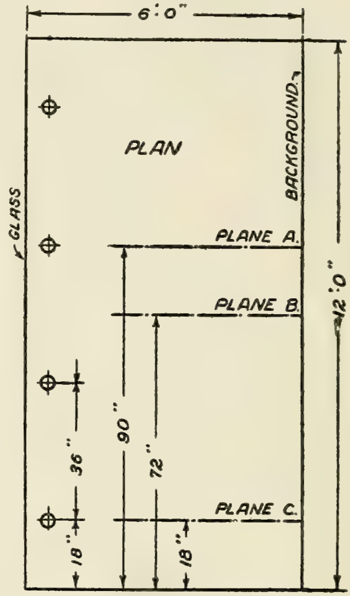


Fig. 31.—Plan of Class C window showing location of test planes and ceiling outlets.

TABLE 6.—SHOWING TEST RESULTS IN CLASS C WINDOW WITH REFLECTOR NO. 755 SHOWN IN FIG. 10.

Centers, 36 in.

Lamps, 100-watt tungsten clear.

Total watts, 409.6.

Number of units, 4.

Holder, 3¼ in. "O."

Watts per running foot, 34.13.

Plane	Station	Average foot-candles
A	1	21.8
	2	22.2
	3	18.4
	4	14.6
	5	12.6
	6	7.7
	7	4.1
B	1	19.7
	2	22.9
B	3	21.8
	4	16.2
	5	11.3
	6	7.3
	7	4.1
C	1	16.5
	2	18.4
	3	18.0
	4	15.4
	5	12.3
	6	7.9
	7	4.3

Average foot-candles, 14.16.

Area of surface along line of trim, 114 sq. ft.

Effective lumens, 1610.

Effective lumens per watt, 3.93.

Total lumens of lamps alone, 3862.

Efficiency of utilization, 41.7.

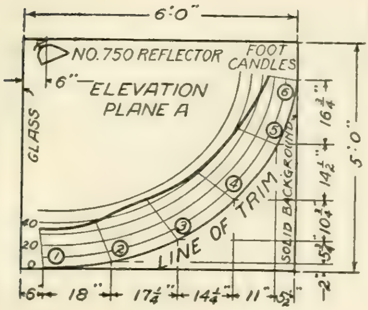


Fig. 32.—Elevation of Class D window showing uniformity of normal illumination along the line of trim.

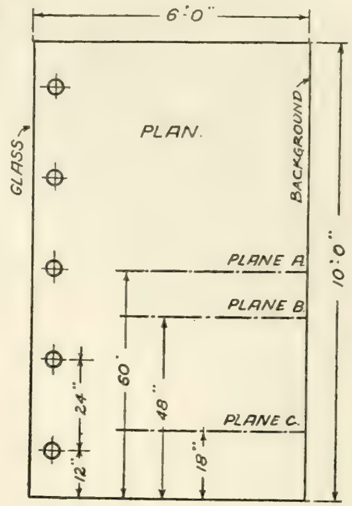


Fig. 33.—Plan of Class D window showing location of test planes and ceiling outlets.

TABLE 7.—SHOWING TEST RESULTS IN CLASS D WINDOW WITH REFLECTOR NO. 750 SHOWN IN FIG. 15.

Centers, 24 in.

Lamps, 60-watt tungsten clear short base.

Total watts, 623.4.

Number of units, 5.

Holder, special.

Watts per running foot 62.34.

Plane	Station	Average foot-candles
A	1	34.2
	2	37.6
	3	45.0
	4	42.8
	5	37.2
	6	26.0
B	1	38.6
	2	43.6
B	3	47.5
	4	46.7
	5	35.5
	6	25.8
C	1	26.9
	2	38.6
	3	43.0
	4	37.3
	5	33.4
	6	22.7

Average foot-candles, 36.8.

Area of surface along line of trim, 86.24 sq. ft.

Effective lumens, 3170.

Effective lumens per watt, 5.08.

Total lumens of lamps alone, 5642.

Efficiency of utilization, 56.2 per cent.

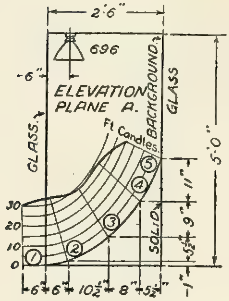


Fig. 34.—Elevation of Class E window showing uniformity of normal illumination along the line of trim.

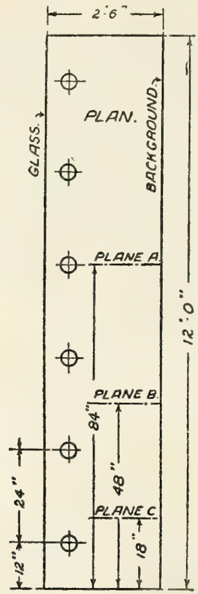


Fig. 35.—Plan of Class E window showing location of test planes and ceiling outlets.

TABLE 8.—SHOWING TEST RESULTS IN CLASS E WINDOW WITH NO. 696 REFLECTORS, SHOWN IN FIG. 19.

Centers, 24 in.

Lamps, 60-watt tungsten clear short base.

Total watts, 372.45.

Number of units, 6.

Holders, 2¼ in. "O."

Watts per running foot, 31.04.

Plane	Station	Average foot-candles
A	1	30.0
	2	32.9
	3	28.3
	4	28.0
	5	20.3
	1	25.5
B	2	30.1
	3	26.2
	4	30.5
	5	19.3
C	1	18.6
	2	23.6
	3	21.7
	4	21.8
	5	16.2

Average foot-candles, 24.8.

Area of surface along line of trim, 40 sq. ft.

Effective lumens, 992.

Effective lumens per watt, 2.67.

Total lumens of lamps alone, 3349.

Efficiency of utilization, 29.7 per cent.

The results obtained in Class B and C windows I believe are best. A high intensity of illumination at the bottom and front of the window with a gradual decrease up to the top of trim seems to give the desired stage light effect in this class of windows.

In the Class A, D and E windows the illumination intensity along the line of trim is nearly constant. A very good effect is secured in each case.

Tests in the various windows run with the reflectors with various spacings, as would be expected, showed that the average intensity of illumination along the line of trim varies practically inversely with the spacing of the units.

The tests in Class A, B and C windows reported here, are representative of the intensities I have recommended for the average size city. Windows of the classes D and E are more prevalent in larger cities and hence the tests reported here show higher intensities of illumination.

The chart for determining the type of reflector required for a given window, and the table giving the spacings for the various reflectors, check out with the test results.

The reason that the No. 777 and No. 750 (Figs. 2 and 15 respectively) reflectors show efficiencies of utilization considerably above any of the other reflectors, is evident because the area in which the light is to be distributed is large and takes in a wide angle. No difficulty is experienced in confining the maximum flux from the lamp in this area.

In the case of the No. 755, No. 780 and No. 696 reflectors, (Figs. 10, 7 and 19 respectively), the area in which the light flux is to be directed is relatively smaller, and takes in a much smaller angle. It is this fact that causes the resultant lower efficiencies of utilization. Of course it would not be desirable to cut off all light outside the angle subtended by the line of trim, but for the best effect and most efficient results the largest portion of the light flux must be confined to this angle.

The No. 696 reflector (Fig. 19) as has been previously explained, allows too much light to escape outside of the angle subtended by the line of trim. A class E window equipped with a

reflector having a distribution of light like that of Fig. 10, would show a much better efficiency of utilization.

The reflector shown in Fig. 7 should not show a lower efficiency of utilization than the reflector of Fig. 10. The difference shown by the test is due to the fact, that the No. 780 (Fig. 7) reflectors tested, happened to be the first ones taken from the mold. This mold after a few reflectors have been run, becomes much smoother and the later reflectors show a very much increased efficiency. The efficiencies of the latter two reflectors used for these tests have been determined and show approximately the same difference.

In order to obtain an idea as to how much the walls and ceiling of the windows add to the total illumination on the line of trim by reflection, tests were run on a class A window with the walls, ceiling and floor covered with black cloth. The conditions of the previous test in the class A window were duplicated with the exceptions noted above. The result of these tests were as follows:

Average foot-candles	14.70
Area of surface along line of trim	168 sq. ft.
Effective lumens	2470
Effective lumens per watt	4.92
Total lumens of lamps alone	4546
Efficiency of utilization	54.3 per cent.

Comparing these figures with those on the light oak window, it is apparent that 7.37 per cent. light flux is reflected onto the line of trim by the walls and ceilings of the window. This added illumination will be more or less depending on the type of window and interior finish. The light oak window was chosen as a good average finish.

CONCLUSION.

As noted at the beginning of my paper, the subject of window lighting has received only a limited amount of attention from the society, and I trust I have started something which will lead to more investigations in this direction. It is a subject well worthy of the attention of the illuminating engineer, the reflector manufacturer, the lamp manufacturer, the electrical contractor, and the central station. It is always possible to interest

a merchant in the true advertising value of a well illuminated window display, because he can see increased business. It is a monetary consideration with him. He is open to conviction when the question of increasing sales is under consideration.

In addition to this, however, beautifully illuminated show windows enhance the beauty of a city, and thus will receive the endorsement of the populace as a public benefit.

I wish to acknowledge valuable suggestions in preparing this paper from Messrs. J. R. Cravath, J. B. Jackson, and L. V. James, associate, electrical engineering department, University of Illinois, and for the assistance of the engineering department of the National X-Ray Reflector Co.

NOTE: The reflectors referred to by number in this paper are manufactured by the National X-Ray Reflector Company, Chicago, Ill.

DISCUSSION.

MR. J. R. CRAVATH, Chicago: I believe with Mr. Little that the surface brightness in the line of trim as seen from the street should be the criterion by which we should make our installation, but I also think that Mr. Wheeler's method practically gives us that within a very narrow margin of error, because we can see by his method that he moved a diffusing test plate up and down almost along the line of trim or very close to it.

The main point I want to make is something in regard to architecture of show windows. It has been said that we must take show windows as we find them; but there are frequently cases where a merchant is remodelling his show windows to make them more effective and the illuminating engineer ought to be in a position to recommend the dimensions which will make it possible to bring out the goods to the best advantage. We all know that show windows are at their best at night under artificial illumination rather than in the day time; therefore their proportions should be selected or should be designed to give the best results under artificial illumination. Experience has proven that the type of window which Mr. Wheeler classifies as a Class C, that is, one with the height two times the depth, does not give good results with artificial light; the result simply being that the vertical illumination that shines on the goods is comparatively low. This applies to dry goods. Of course with jew-

elry it is altogether different. It is almost impossible to avoid having dry goods cast shadows on themselves in such shallow windows. I prefer for dry goods a deep window as that type makes possible the best illumination of the goods.

Mr. W. F. Little: In addition to this very valuable paper, would it not be well to make further investigations showing the surface brightness of the various objects in the line of trim? While the foot-candle intensities as given by Mr. Wheeler are of prime importance, still surface brightness measurements showing the range of contrasts met with in a window trimmed with various materials would be of considerable interest.

Mr. H. B. Wheeler (In reply): Regardless of the class a window falls into, the practise of using mirrored backgrounds should be discouraged, as images of surrounding articles are generally present, which detract from the goods on display.

Under typical windows in the large cities on the main streets, the merchant is very anxious to obtain the full advertising value of his window; and hence demands a high degree of illumination. Thirty-foot candles has been found ample illumination for typical windows with medium decorations.

From the data presented in this paper, you will note that concentrating reflectors are used in comparatively high windows, and hence are at a considerable distance from the goods on display. Further the reflectors are designed to allow plenty of radiation. I have never heard of any case where the light rays from commercial types of concentrating reflectors, had ever done any damage in the least to the most delicate goods in a window.

A further investigation of surface brightness would be very interesting, and I trust that further investigation on this subject will be gone into.

My paper was based on average conditions typical of fairly modern show windows. Medium colors were selected as fairly representative for the ends, background and ceiling of the various windows tested.

MODERN PRACTISE IN STREET RAILWAY ILLUMINATION.*

BY S. G. HIBBEN.

Synopsis: Up to the present time street car lighting has been done inefficiently, with bare carbon filament lamps. Recently four standard tungsten lamps have been placed on the market, which in conjunction with proper downward reflecting shades have enabled the energy cost for lighting to be cut in half, at the same time allowing an increase in the usable light of more than 80 per cent. Special fixtures are available for supporting the shades, and selector switches may be employed to insure continuous lighting service of series burning lamps. Steadier illumination is secured by the new system of lighting, under the adverse conditions of voltage fluctuations, and the glare that exists at present in the majority of electrically lighted street cars is done away with through the medium of the shades. The scientific, economical lighting of street cars is a field that is full of interesting possibilities, and is now being very rapidly developed.

Although the incandescent filament lamp has been used for the lighting of street railway cars practically ever since the electric motor cars superseded the horse or cable cars, it has not been until within the last six years that any attempts have been made to utilize the generated light to best advantage by means of scientifically manufactured shades or reflectors; and it has not been until about one year ago that the tungsten-filament lamps of an efficiency of 1.4 watts per horizontal candle or better, have been perfected to the extent of being sufficiently rugged for this street railway service. Consequently the economic and scientific illumination of street cars has been slow in its inception and development, compared with the rapid progress that has been made in the lighting of large office buildings, stores, residences, or even steam railway cars.

There are several reasons for this slow development. Lighting energy, being but a small fraction of the total energy used by motors, and being relatively cheap to generate, has not been considered as a fit subject for economy. Also the short periods

* A paper read at the seventh annual convention of the Illuminating Engineering Society, Pittsburgh, Pa., September 22-26, 1913.

that individuals of the traveling public use the lighting, and the disposition of passengers to make the best of the illumination, unless it be absolutely unbearable, has not been conducive to public protestations. Furthermore the rough usage to which lamps and shades are necessarily subjected, the low first cost of the carbon filament lamps, the uncertain relations between private street railway corporations and municipalities, have all been reasons for slowness in arriving at modern car lighting. How really vital these reasons are will be left to be judged after a further consideration of this paper.

As far as the author can determine, the first street car using individual reflectors on lamps was put in service in 1909, this being a car of the Oakwood Traction Co., operating in Dayton, Ohio, although previously there may have been a few desultory attempts to equip lamp clusters with reflecting glassware. This car was equipped with center-deck 4-light fixtures, and side wall single light brackets, using square shaped alba glass shades. A view of this car is shown in Fig. 1. Cars with this equipment are still in service.

About two years ago a number of traction companies installed bare 23 and 36-watt tungsten filament lamps replacing the carbon lamps, having their attention directed chiefly towards determining the ultimate lamp life. When the majority of these new lamps had shown a life of 1,000 to 1,300 hours, the progress was rapid towards the standardization of the present series burning lamps, and the shade, holder, and switch devices as accessories. The description of such modern equipment and a discussion of its operation constitutes the subject-matter of this paper.

PAST PRACTISE.

The lighting of street cars has previously been accomplished by using bare carbon, and in a few cars, graphitized filament lamps. It has required from a dozen to thirty of the so-called 16 candle-power 64-watt carbon lamps in the car body, and eight to ten similar lamps distributed on platforms and in the headlight and designating signs. Between bulkheads the lamps were placed about 18 inches (45.72 cm.) apart in line along the center deck, or studded over the whole ceiling, or else grouped

in clusters of four, five or as many as eight lamps arranged radially from single fixtures on the center deck ceiling. Such carbon lamps usually burned five in series on the nominal 550 volt power circuit, each being rated at 110 volts.

The high current consumption of the carbon lamps, together with their poor illuminating performance, has led to the substitution of, first, the metallized or gem lamps, and second, the bare 23-watt tungsten lamps in the same sockets. The former lamps are proving unsatisfactory on account of filament breakage from jarring and other objections,[1] while the small unshielded tungsten lamps are but a temporary makeshift, due to excessive glare, and because no attempt is made to utilize the maximum amount of generated light, or direct it downward.

PRESENT METHODS.

The most modern car lighting equipment consists of one circuit of five tungsten lamps, of the 94-watt, 78 candle-power size, arranged in line along the car ceiling, or else an arrangement of two circuits of five each, of the 56-watt, 46.7 candle-power tungsten lamps. Quite often, in the cars where the 94-watt lamps are used, these are placed four in the car body between bulkheads, and one over the entrance vestibule, especially if the car is of the pay-enter type. In other types of cars, such as the interurbans, there may be three units in the passenger compartment, one in the baggage or smoking room, and one in the vestibule. An additional circuit of five 23-watt tungsten lamps is recommended for the large types of city cars, particularly if these cars have the one circuit of 94-watt lamps. The small lamps are arranged over the steps, in the headlight, and in the illuminated designation signs.

Sometimes, but not often, the fourth size of modern lamp, a 36-watt, 26.8 candle-power tungsten-filament is used in the car body, but the cases where the 23-watt or the 36-watt lamps are being employed between bulkheads are largely those where no new wiring or accessories are being installed, and where these small lamps are replacing the carbon lamps in the old sockets or receptacles.

[1] The average life of Gem lamps in street railway service is found to be 900 hours or less, although with the exception of a few isolated cases, the life is nearer 700 hours.

The four lamp sizes mentioned above are the ones that are so far standardized for street railway service. Their characteristics may be found in the following table:

TABLE I.—CHARACTERISTICS OF TUNGSTEN-FILAMENT STREET RAILWAY LAMPS.

Watts	Hor. C-p.	Watts per C-p.	Lumens	Avg. Hrs Life	Bulb Diam.	Overall Length
23	17.1	1.34	168	2,000	2-3/8	5-1/4
36	26.8	1.34	263	2,000	2-3/8	5-1/4
56	46.7	1.20	457	2,000	2-5/8	5-3/8
94	78.3	1.20	767	2,000	3-1/16	7-1/8

Any of these lamps are procurable for a power line voltage of 525 to 650, or with individual ratings of 105 to 130 volts. They are sturdy in construction, and selected for the current to insure a uniformity of candle-power and life.

The wiring circuits of two typical systems are given in Figs. 2 and 3. In Fig. 2 may be seen the arrangement of the 94-watt lamps that is excellent because it insures continuous lighting service. An extra unit is used, commonly short-circuited by a selector switch as shown, and thus in the event of the failure of any one lamp, (which would leave the whole car in darkness), the manually operated selector switch may be turned by the conductor or motorman, bridging successive lamps until the burnt-out one is short-circuited, while meantime the extra unit (usually in the rear vestibule) comes into circuit, and the failure may be replaced at the first convenient point on the run. On the whole, this wiring arrangement seems to be the most advisable one. This scheme is all the more advantageous when a three-way switch is wired in the circuit, and when a seventh unit is installed in the front vestibule. A car with this arrangement may always have well illuminated steps and entrances, for in loading or unloading, the conductor may bridge a unit in the passenger compartment, and burn both vestibule lights. Then, whichever way the car is running, he may so manipulate the two switches as to have a rear platform light, as well as all lamps between bulk heads burning.

Fig. 3 shows an arrangement of two independent circuits of 56-watt lamps, and since no selector switch is used, any one

Fig. 1. The first street car systematically equipped with reflecting shades.

Fig. 1a.—View of selector switch and one ceiling unit.

Fig. 4.—One of the modern units used for street railway car lighting.

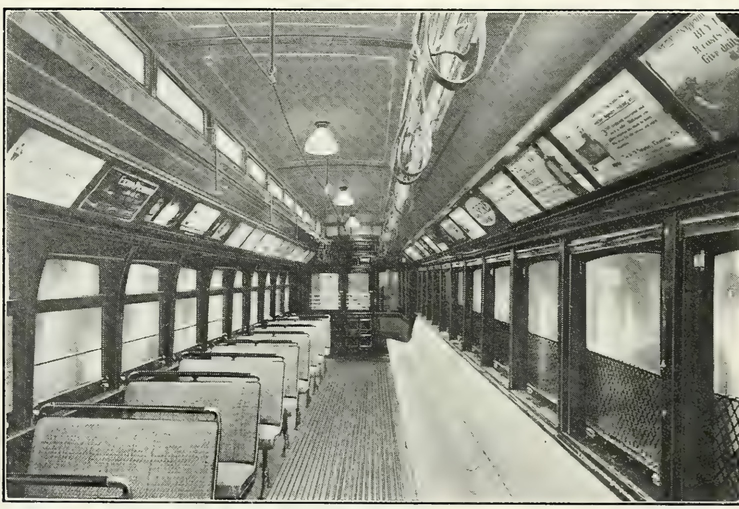


Fig. 5.—View of street car using 94-watt tungsten lamps and shades.

lamp failure will leave half but not all of the car in darkness temporarily. Fig. 1a shows a portion of the rear platform with a selector switch and one ceiling unit in place.

All lamps in the most modern street cars are being equipped with downward reflecting shades, for reasons hereafter explained. Fig. 4 illustrates one such type of shade, together with the holder that in reality is the complete fixture. Several forms of holders are available; one style is shorter than the one shown

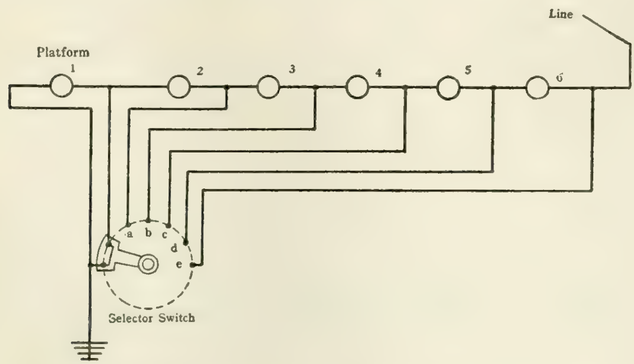


Fig. 2.—Wiring diagram for a circuit of 94-watt or 56-watt tungsten lamps.

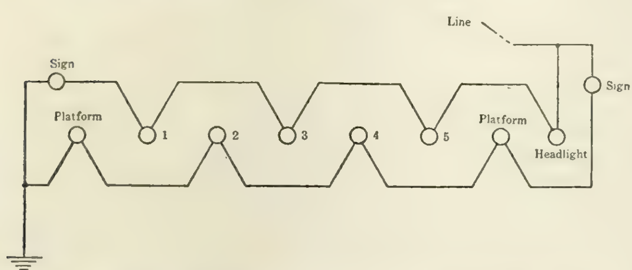


Fig. 3.—Wiring diagram for lamps in two independent circuits.

in Fig. 4. These holders all operate to clamp the neck of the glass shade all around, with a firm grip that cannot jar loose, and in such a way that there is no probability of breakage if a well made shade is used.

Fig. 5 shows the interior of a typical city car, where the units are of the 94-watt type, with a deep bowl alba glass shade. The

plan of this car is given in Fig. 6, from which the location and spacing of the main lighting units can be seen.

ILLUMINATION COMPARISONS.

Two main factors are the criteria of the satisfactory qualities of the lighting system—the cost, and the illuminating performance. The latter consideration involves the measurable amount of foot-candles at the desirable places, and also the quality of the light that is furnishing these foot-candle values, and its physiological effects.

Anyone who has seen a car illuminated by the shaded lamps, and particularly if this car has both shades and bare lamps that can be alternately burned, will not question the fact that there

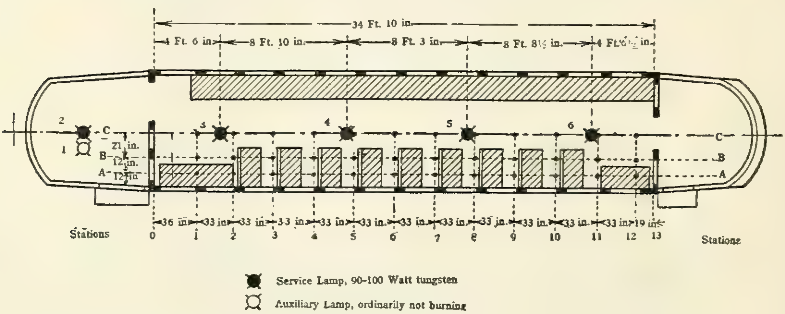


Fig. 6.—Plan of car shown in Fig. 5, showing location of lamps and test stations.

is a remarkable difference in the qualities of the light from the two arrangements. The glare from the bare light sources is particularly aggravating in street cars, and all-frosted bulbs will not do much to correct the fault. Bare carbon lamps of low brilliancy might be bearable, but bare tungsten lamps never. The car ceilings are low, and there is a vista along which the eye gazes. There are usually advertising cards to attract the attention towards the upper parts of the car, and there are unavoidable changes of the intensities from jarring and voltage fluctuations that soon tire the accommodating muscles of the eye. Hence the street railway lamps should unquestionably be equipped with shades that at least protect the eyes of the passengers.

Every street railway must operate its lighting circuits and its power circuits as one. Hence at the very time when the lights

are most needed, the load on the system is the greatest, and the fluctuations of voltage are increased correspondingly. This trouble from voltage fluctuations was very apparent with the use of carbon filament lamps,[1] but it becomes very much less troublesome with the tungsten lamps, since their candle-powers do not change so rapidly at the different pressures. This can be seen in Fig. 7. For instance, if both types of lamps gave their full rated or 100 per cent. candle-power at 500 volts, then when the voltage fell to such a value as 440, as it often does on street cars, the tungsten lamps would still give 60 per cent. of their initial candle-power, but the carbon lamps would be furnishing

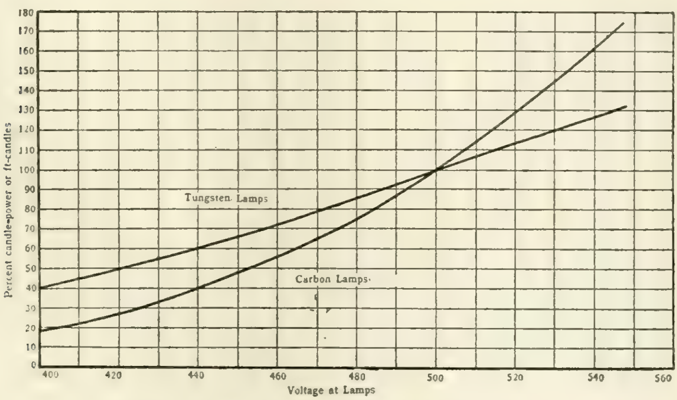


Fig. 7.—Voltage candle-power variation curves.

only 40 per cent. candle-power. If a lighting installation is originally planned to furnish a certain adequate illumination at the minimum voltage, it can easily be seen how much greater must be the investment, and the waste, in doing this with carbon rather than with metal filament lamps.

As to the actual foot-candle values in a typical car, note the plotted results of photometric tests that appear in Figs. 8, 9, and 10. Fig. 8 shows the transverse and longitudinal distributions in the car which is shown in Fig. 5. Here the typical differences between the bare carbon, and the shaded tungsten lamps is indicated. In Fig. 6 are shown the test stations at which horizon-

[1] In fact over 35 per cent. of the operating companies report considerable trouble from this source.

tal foot-candles were measured, at the reading height of 37 inches. In Fig. 8, the dotted lines represent the results from the bare carbon lamps, seventeen of which were burning between the bulkheads. These carbon lamps were in clusters, five above test station 8-C, four above each of the three stations 11-C, 5-C, and 2-C (see Fig. 6). Compare the longitudinal distributions along lines A and B, obtained from these seventeen carbon lamps, with the illumination furnished by the four 94-watt tungsten lamps with shades, that were placed as shown in Fig. 6. The averages of lines A and B with the bare carbon lamps, are 1.9 and 2.4

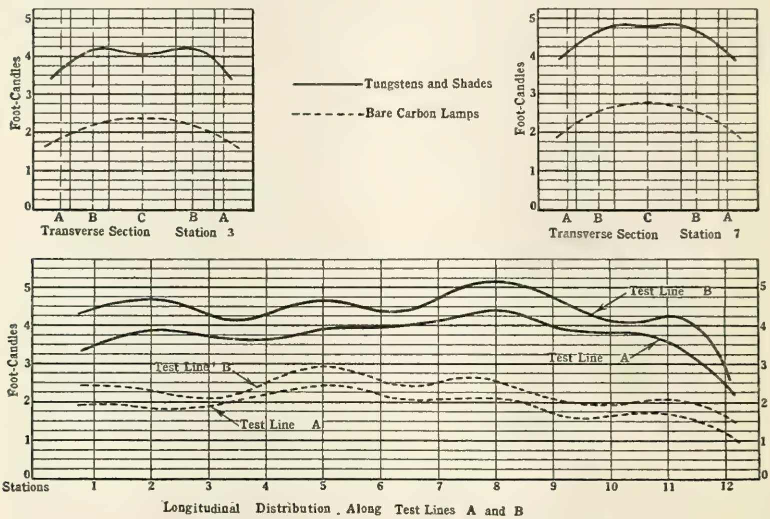


Fig. 8.—Illumination curves from tests of car shown in Figs. 5 and 6.

foot-candles respectively. The corresponding averages with the tungsten lamps and shades are 3.74 and 4.32. Down the aisle (test line C) the average with carbon lamps is 2.6 and with the shaded tungsten lamps 4.53, so that when considering the whole car, the total averages are 2.24 for carbon, and 4.13 for tungsten lamps with shades.[1]

This is the typical comparison between bare carbon lamps and shaded tungsten lamps. The following table gives the detailed story:

[1] In averaging, double weight is given to lines A and B, to arrive at a true average for whole car.

TABLE II.—ILLUMINATION DATA——BARE CARBON VS. SHADED TUNGSTEN LAMPS.

	Bare Carbon	Shaded Mazda
No. of lamps	17.0	4.0
Candle-power per lamp	16.3	75.0
Watts per lamp	64.0	91.0
Total watts	1088.0	364.0
Total generated lumens	3570.0	2952.0
Area car floor	278.0	278.0
Watts per square foot	3.91	1.31
Average foot-candles	2.24	4.13
Useful lumens	623.0	1150.0
Utilization factor	17.5%	39%
Relative efficiency	45%	100%

As regards the illumination when small bare tungsten lamps are substituted for bare carbon lamps, a test was made in the car of Fig. 5, in which the arrangement of carbon lamps was in groups as previously mentioned, and which was the same as the arrangement of the 23-watt tungsten lamps.

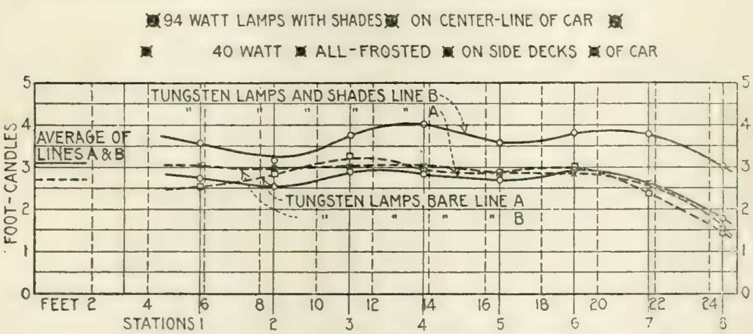


Fig. 9.—Illumination curves from tests in car shown in Fig. 11.

With the carbon lamps, the averages along lines A, B, and C were as before, namely 1.9, 2.4 and 2.6 foot-candles. The 23-watt bare tungsten lamps gave corresponding foot-candles of 2.1, 2.6 and 2.9. The total car average illumination in the two cases was 2.24 and 2.46, or a gain of practically 10 per cent. in foot-candles resulting from the use of the tungsten lamps. The utilization efficiency of the bare tungsten lamps was 24 per cent.

A third test will show the comparison of bare all-frosted tungsten lamps vs. clear bulb tungsten lamps with shades. Fig. 9 shows the longitudinal distribution in a car of the plan shown

by Fig. 11, the full lines representing horizontal foot-candles from the 94-watt lamp, and the dotted lines, the results from the all-frosted bare 40-watt lamps. Fig. 10 shows the transverse distribution of these latter two cases. (Fig. 10 is a section at station 3, Fig. 11.)

The car between bulkheads in this case had three 94-watt tungsten lamps on the center deck ceiling, and eight 40-watt round bulb tungsten lamps arranged along the side decks. These latter unshaded lamps gave a bad glare, and were left in the

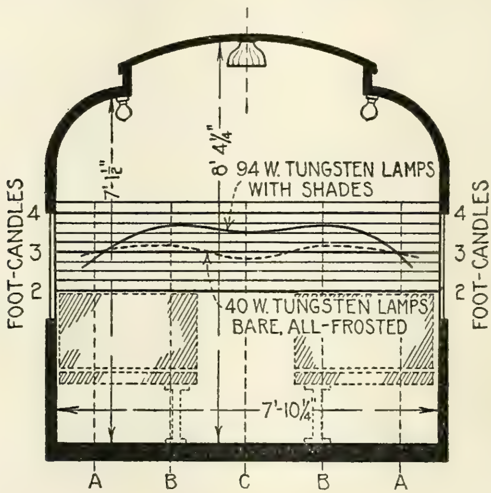


Fig. 10.—Illumination of car shown in Fig. 11, taken at station No. 3.

car only to afford two emergency lighting circuits. The following table gives the details of the tests recorded in Figs. 9 and 10:

TABLE III.—ILLUMINATION DATA—BARE VERSUS SHADED TUNGSTEN LAMPS.

	Bare Tungsten lamps	Shaded Tungsten lamps
No. of lamps	8.0	3.0
Candle-power per lamp	30.0	75.0
Watts per lamp	39.0	84.3
Total watts	312.0	253.0
Total generated lumens	2560.0	2142.0
Area car floor	194.0	194.0
Watts per square foot	1.62	1.31
Average foot-candles	2.71	3.24
Useful lumens	525.0	628.0
Utilization factor	22.08%	29.30%
Relative efficiency	75%	100%

It may be interesting to note that at stations 3-A, 3-B and 3-C of Fig. 11, the foot-candles on a plane 45° to the rear were 1.68, 2.34 and 2.31. At stations 6-A, 6-B and 6-C the values were 1.97, 2.52 and 2.59 foot-candles.

A summary of the above three cases indicate that (1) bare carbon lamps are hardly comparable with shaded tungsten lamps, being very inefficient. (2) Replacing carbon lamps with small bare tungsten lamps is not advisable and affords but a small gain in the quantity of the illumination (greatly increasing the harshness of the light), although considerably reducing the wattage. (3) Using all-frosted tungsten calls for a consumption of more energy and produces much less useful light than shaded tungsten lamps. (4) Tungsten lamps properly

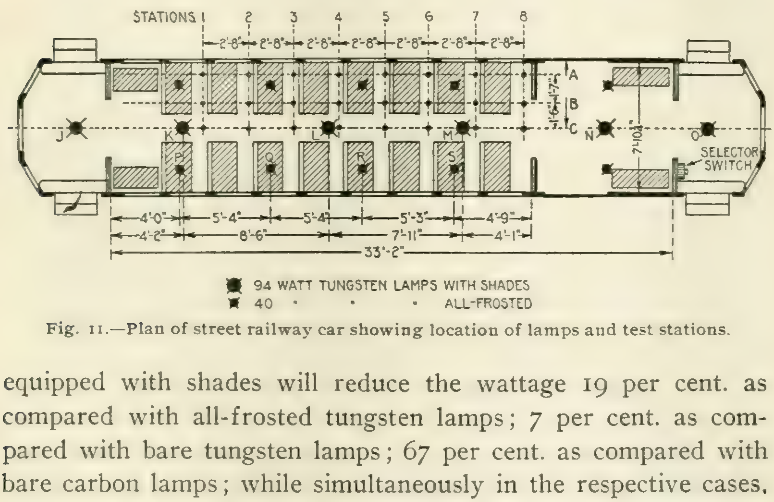


Fig. 11.—Plan of street railway car showing location of lamps and test stations.

equipped with shades will reduce the wattage 19 per cent. as compared with all-frosted tungsten lamps; 7 per cent. as compared with bare tungsten lamps; 67 per cent. as compared with bare carbon lamps; while simultaneously in the respective cases, the shaded tungsten lamps will cause increases in illumination of 19.5 per cent.; 68.0 per cent. and 84.5 per cent.

COST COMPARISONS.

No matter how photometrically efficient a lighting system may be in furnishing the requisite foot-candles, that system will be inadvisable in traction service if it is not one whereby a monetary saving will be accomplished, either directly by a saving of operating costs, or indirectly through the medium of pleased passengers and greater patronage. The new shaded tungsten

filament lamp systems can accomplish both of these desired results.

The value of a proportionately small[1] saving in energy in street railway operation is seldom given full consideration, because of its low cost of generation. But energy at the car is more expensive than power-house costs indicate, and any saving of it through the modern system of car lighting will be appreciable. In general, power at a car will average about 1.5 cents per kilowatt-hour. When a system of cars averaging twenty-two 64-watt carbon lamps per car is changed over to use five 94-watt tungsten lamps, the energy saved is 938 watts,

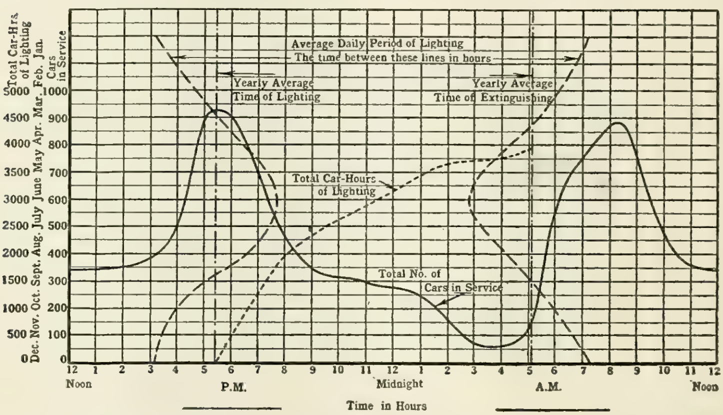


Fig. 12—Characteristic curves of a typical street railway system.

amounting to 1.4 cents per car hour. If there are 1,000 cars on the system, it has been found that there will be about 1,500,000 car hours of lighting per year, on the average, making a total saving per year of $21,000. The cost of the shade equipment, the excess of the cost of tungsten lamps over carbon lamps, and the cleaning expenses, will of course reduce this savings perhaps 20 per cent.

Approaching the problem of economics from a different angle, one may consider Fig. 12, which shows the characteristics of a

[1] A 34-ton car with 25 passengers, consumes in its two 75 horse-power motors about 128 amperes at 500 volts.

representative street railway system. In this figure the full-line curve represents the total number of cars in service at any particular hour of the day. The dashed-line curve in the shape of the hyperbola represents, for the various months of the year, the time of lighting and of extinguishing the lamps. The dotted line gives a summation of the total car-hours of lighting for one period of darkness, being based on a yearly average. In tabulated form, a representative lighting schedule is given as follows:

TABLE IV.—A TYPICAL STREET RAILWAY LIGHTING SCHEDULE

Months	Period of Lighting	Hours per Day	Hours per Month
January	3:35 P. M. to 6:50 A. M.	15:15	472
February	4:15 P. M. to 6:20 A. M.	14:05	394
March	5:00 P. M. to 5:45 A. M.	12:45	395
April	5:50 P. M. to 4:50 A. M.	11:00	330
May	6:50 P. M. to 3:45 A. M.	8:55	276
June	7:35 P. M. to 3:00 A. M.	7:25	222
July	7:40 P. M. to 3:00 A. M.	7:20	227
August	7:00 P. M. to 3:45 A. M.	8:45	271
September	5:50 P. M. to 4:45 A. M.	10:55	328
October	4:30 P. M. to 5:40 A. M.	13:10	408
November	3:40 P. M. to 6:20 A. M.	14:40	440
December	3:15 P. M. to 6:55 A. M.	15:40	486
[1]Average	5:25 P. M. to 5:05 A. M.	11:37	354

When considering the average number of cars in service during each hour of the dark period, and multiplying this number by the hours each car is lighted, it is seen that, for each day, there will be approximately 3,900 car-hours of lighting on this 1,000-car system. This amounts to 1,500,000 car-hours per year. Now a careful analysis made by other authorities, of power costs of this representative system, based on the wattages of the old carbon lamp and the new tungsten filament lamp and shade equipment, show a total cost of lighting power per year of \$35,500 and \$14,150 respectively. Therefore a summary of lighting costs will be about as follows:

[1] In southwestern United States, and in agricultural or similar regions having much clear weather the average hours per month falls as low as 225.

TABLE V.—LIGHTING COSTS, WITH THE NEW AND THE OLD SYSTEMS.

	Carbon lamps	Tungsten lamps	
Car-hours of lighting per year	1,500,000	1,500,000	
[1] Average number of lamps per car	22.38	5-94 watt	4.48-23 watt
Lamp hours of lighting per year	33,600,000	7,500,000	6,730,000
Average life of lamp in hours	1,800	2,000	2,000
Yearly number of lamp renewals	18,650	3,750	3,365
Net cost of lamps (on $2,500 contract)	$2,238.00	$2,396.25	$955.65
		$ 3,352.00	
Yearly cost of power for lighting	$35,500.00	14,150.00	
[2] Estimated expense of shade equipment	—	2,000.00	
Final total yearly cost	$37,738.00	$19,502.00	

The above figures, showing a probable saving of $18,000.00 or $18.00 per car per year, compare closely with the estimate as previously presented, and moreover they represent a very conclusive argument for the adoption of the modern lighting system. This is but the financial viewpoint, and one should not loose sight of the accompanying increase in the amount of light (84 per cent. increase, see table 11) nor of the better qualities of the illumination.

SUMMARY OF THE STATUS AND PROSPECTS OF CAR LIGHTING.

Briefly, the most important considerations to the gathered from the above discussions are summarized as follows:

The bare carbon or graphitized filament lamps are no longer advisable nor economical for street railway service, on account of short life, high energy consumption, poor quality and unsteadiness of light, and the wiring costs incidental to the installing of a large quantity of them.

Small bare tungsten lamps replacing them are nearly as wasteful from the standpoint of not having their light directed by proper shades, and in addition are extremely dazzling and optically harmful.

Large tungsten lamps, of 94 or 56-watt sizes, seem the most

[1] The fractions of lamps come from an average of motor-cars and of trailers, the latter having fewer lamps, and in the case of the tungsten lamps, having but the one circuit of five 94-watt units.

[2] Based on (1) First cost $7,000, or interest of $280.00. (2) 10 per cent. breakage and depreciation, or $700.00. (3) Cleaning twice monthly $1.05 per year per car or $1,050.00. As regards this cleaning expense, the data is meager. A fair figure for dusting once daily seems to be 60¢ per car per month, and washing twice monthly, 60¢ to $1.25 per car per month.

economical, in conjunction with shades. These units may more than double the previous (most generally inadequate) values of illumination, at one-third of the energy cost, giving a soft diffused light and forming a neat decorative unit.

The candle-power of the tungsten lamps is much more steady and less affected by voltage fluctuations.

The net cost of lighting with the new units is much less than when carbon lamps are used; the cost of the tungsten lamps is slightly greater, but this is more than compensated for by the energy saved.

All these items, and others that appear from a study of this subject, seem to indicate a prospect—almost a certainty—of a rapid and a large development in street railway car lighting. Up to the present time there have been perhaps a half dozen installations of large tungsten units, and shades. Bare tungsten (together with a few tantalum) lamps are in service on approximately 28 per cent., bare graphatized lamps on 10 per cent., and bare carbon lamps on 60 per cent. of the 175,000 to 200,000 cars in service in the United States.

Very soon the traveling public may be expected to demand better lighted cars. As the passenger looks lengthwise of the car (75 per cent have cross seats) or up at the advertising cards (on 95 per cent. of all cars) he cannot help but be affected by the glare from the old lighting systems. If he may be freed from this annoyance, and does not have to strain his eyes because of insufficient or fluctuating illumination, surely he becomes a more valuable asset to any railway company.

Therefore this modern lighting system seems destined to be mutually advantageous to street railway companies and passengers. It is hoped that further investigations of this subject will soon afford valuable additions to the somewhat preliminary study that this paper presents.

DISCUSSION.

Mr. L. C. Porter: A little over two years ago Mr. Stickney took up the question of street car lighting. We went to several railway companies to put the proposition up to them. The first question that arose was: Will the lamps stand the severe use of street car service? At that time we had results of tests which had been conducted on some of the United States battleships where tungsten lamps had gone through target practise, full power run and several other severe tests, giving very good results. We also had tests on ferry boats where the lamps operated satisfactorily.

With the co-operation of Mr. Holst of the Bay State Street Railway Company, we equipped some of their cars with 56-watt tungsten lamps and prismatic reflectors. The question of the different sized lamps was studied and it seemed best to use the 56-watt lamps for several reasons. The principal reason was that with the 94-watt lamp the failure of one lamp would put the car in darkness for at least a few minutes until the conductor could find the selector switch and operate it; while with the 56-watt lamp there were two circuits, and since the lamps are wired on alternate circuits the failure of one lamp would not plunge the car into darkness. Another advantage which was found in using the 56-watt lamps was that the lamps could be spaced a little closer together, giving less sharp shadows than are likely to maintain in the 94-watt system. For instance, look at the diagram on page 598; and consider a passenger seated in the second seat from the left-hand end of the car, holding his paper on what is an average reading plane; that is, 45° (3 feet above the floor). When facing the right-end of the car the passenger will get very good light on the paper, but when he faces the left-end the illumination on the paper will not be so good, because the light which is then shining on it will come from a considerable distance; whereas if a lamp were placed halfway between, there would be practically the same amount of illumination no matter whether the reader were facing forward or backward.

Twenty-eight-foot cars and 34-foot cars were equipped with 56-watt lamps. In installing this system we spaced the lamps 6

feet apart, in this way bringing the two end lamps 2 feet from the ends of the car, with another lamp on each platform, one in the headlight and one 56-watt lamp in each sign of the car. Where two lamps had been used per sign, we installed 2 28-watt, half voltage lamps (equivalent to one 56-watt, full voltage lamp), thus making two full circuits of 5 56-watt lamps each.

Photometer tests were conducted in cars so equipped and it was found that in a car that had previously been equipped with 25-watt 64 carbon lamps, consuming 1,600 watts, we reduced this consumption to 560 watts by using the 56-watt lamps which gave approximately 3 effective lumens per watt; whereas only 0.4 was obtained with the carbon lamps.

Both intensive and extensive type reflectors were tried. It was found that the intensive type of reflector gave the better results. It gave a better average intensity and threw the maximum amount of light where it was most needed, that is, over the seats.

An interesting shadow test was conducted in which Mr. Holst seated himself in various seats in the car and was surrounded by a number of men, to see if they could cast objectionable shadows over the paper he was reading. It was found impossible to do this.

Six of these cars were operated by the Bay State Company over various conditions of roadbed, continuously for over a year in order to make absolutely sure that both the reflectors and the lamps would stand the service. At the end of the year they had proved very satisfactory. Those tests were reported by Mr. Holst in the *Electric Railway Journal* for September, 1912. As a result of the tests the Bay State Street Railway Company is equipping all of its new cars with this system of lighting and also rewiring some of the old ones. There are several other companies throughout the country that are doing likewise, proving that this system is a paying proposition.

MR. E. B. ROWE: Mr. Hibben's paper is an excellent one for our TRANSACTIONS because it adds something new. Street car lighting, or rather the proper illumination of street cars, is a relatively new development and there are tremendous possibilities in the way of improvements.

During Mr. Porter's discussion it occurred to me that circumstances may alter cases: this should be remembered in discussions of the 56-watt 2-circuit system versus 94-watt 1-circuit system, from the standpoint of lamp failures. The consequences of the total though brief loss of light in a car which would result when a lamp fails in the latter system would depend to a large extent on whether it is totally dark outside of the car and consequently on the territory over which the car operates. In most city streets there is enough external light coming in so that the total failure of the light in the car is not of so much importance, whereas in running over a private right of way or over country roads it is of great importance.

Again, as regards ability to read with the one-circuit and two-circuit systems,—that may depend on the type of car construction. If it is a car having the passengers all facing in one direction and not across the car, the need for good reading illumination, both in intensity and proper direction, is greater than in that type of car which is rapidly coming into favor for conjested city service. My point is that what has proved to be the best type of lighting system for one installation is not necessarily the best type to adopt for some other traction system.

In Mr. Hibben's paper he mentions in his introduction that the first installation of lamps with individual reflectors in street cars was in 1909 in Dayton. I believe there were several isolated instances where single carbon lamps were equipped with prismatic reflectors prior to that date. There is one such installation on the Washington & Baltimore Traction System.

During the past few years or even months, to one who has been following the situation, it is quite remarkable to note the change in attitude regarding this question of car lighting. Several years ago the question of changing the lighting in the subway cars of New York came up under the direction of the Public Service Commission. Extensive tests were made to show what improvement could be effected by change in equipment. These tests brought out clearly of course the advantages from the standpoint of uniformity and higher intensity of using reflectors over the lamps and by substituting tungsten lamps for the carbon

lamps then in use. The danger from glare, however, was not so well understood at that time and the use of reflectors was temporarily decided against because, as one of the managers of the subway company expressed it, "the public was not educated to the need of reflectors." This is an attitude which will probably always require a great deal of effort to overcome. Something really desirable should not be turned down because the public has not been "educated up to it." I believe the change should be made and the advantages proved in actual practise.

The use of a spare lamp with the selector switch gives a very satisfactory system of illumination. On the Cleveland cars the newer ones have the extra lamp placed in a similar fitting to the lamp in service over the rear platform, these two lamps being placed close together in individual porcelain enameled bowl-shaped reflectors which are counter sunk in the ceiling of the car. These reflectors with the prismatic reflectors used in the body of the car provide a very satisfactory system giving practically no glare effect; and the steps, platform and seats are amply lighted. As these are pay-enter cars the selector switch is always within easy reach of the conductor and only a few seconds are required to locate the dead lamp, in case of a failure, and replace it by the spare lamp at the first convenient opportunity.

The effect of changing from carbon to tungsten lamps from the standpoint of change in intensity with voltage variations is, I believe, quite noticeable to anyone who has used a line frequently before and after such a change. On the Columbus-Zanesville Interurban Line I had an opportunity of observing this fact and while I knew what to expect I was actually astounded by the improvement after the substitution of the tungsten lamps. Before the change when a car pulled out of the Columbus station it was necessary to stop reading, roll up one's coat for a pillow and try to get some sleep; the voltage dropped so much that the car was almost in darkness. After the tungsten lamps were put in one could read fairly comfortably during the entire trip, even though the voltage fluctuation on that line is quite extreme.

The use of auxiliary emergency lighting might be mentioned because this ought sometimes to be provided on lines where an

absolute or extended failure of the service might result in panics and serious accidents. The use of a small storage battery equipment with a few lamps placed at convenient points in the car will provide light instantly when other sources fail.

It may be interesting to the I. E. S. members to follow a series of tests in a study of coach lighting which has just been conducted under the auspices of the Railway Electrical Engineers. Although these tests were conducted with primary reference to steam road conditions, the illumination requirements in coaches are so similar to those in street and interurban electric cars that these tests should be of considerable help in designing the lighting systems for electric cars. These tests were quite extensive, involving a consideration of shadow effects, etc., and will undoubtedly be published in full shortly.

Mr. G. H. Stickney: I believe thoroughly that the use of reflectors with tungsten filament lamps in street car lighting is the coming practise, both on account of the superior lighting effect and economy. (The installation of such units on the Bay State Street Railways, described in the *Railway Electrical Engineer* of September 28th 1912, was the first of the recent installations of this type.) On the other hand, I cannot quite agree with the author that the use of the bate tungsten filament lamp is not justified, at least as a temporary expedient, for certain conditions. In the first place, on account of the expense and time required to rewire and equip old cars already in active service, it is impracticable for many roads to change over completely immediately. In the second place, the demand for soft, diffused light in street cars is nowhere near as great as in train lighting or other interior lighting installations, since the passengers are not in the cars for relatively long periods of time, and, wearing hats, they do not have their eyes exposed to the glare to the same extent as under these other conditions. I have ridden in the subways in New York, which, as you know, are equipped with bare tungsten filament lamps, and it has been my observation that relatively few of the passengers have been conscious of the glare effect, while many have appreciated the higher intensity provided and the improved steadiness of the light under voltage variation, which

is a very decided advantage introduced by the tungsten filament lamps, whether with or without reflectors.

I firmly believe that the question of economy alone should induce the railways to immediately adopt reflectors in all new cars, and that in the long run it will compel their adoption even at the expense of re-wiring, for all roads in which costs are carefully figured.

Mr. Porter has mentioned tests in which we are assisting the New York Municipal Railways. I hope that it will be possible to make these tests public, as they are probably some of the most complete yet undertaken. Practically every arrangement of lighting that promises to be suitable for the subway cars in question is being tried out and observed.

Referring again to the paper, the author states that there are half a dozen lines using tungsten filament lamps. I think this is a little conservative, as I am sure we have handled a considerably larger number than that in our own office.

Mr. V. R. Lansingh: The substitution of tungsten lamps for carbon lamps naturally increases eyestrain, and it is a question with me whether or not the economy gained by the use of the new lamps and the increase in illumination is not more than offset by the decrease in eye comfort. Furthermore, when the railroad has made such substitution the economy to be gained by the use of reflectors is smaller than it would have been if they had started in at the beginning and changed the entire system. It is a question, when the new lamps have once been installed whether there would ever be a change to the old wiring system and in new lamps and reflectors installed. I believe I would rather see the old system remain in place and the new complete system will therefore come sooner.

Mr. C. W. Bettcher: I believe that the fluctuation in the candle-power of carbon lamps, due to the change in voltage, is much more objectionable than the glare from the tungsten filament lamps when they are installed. Most people do not care so much about the glare; in fact they do not notice it when reading; but certainly the change in candle-power is very objectionable, especially where a good many stops are made and frequent starting causes a temporary drop in voltage.

Mr. Ward Harrison: In comparing the relative advantages of the 56 and 94-watt lamps, the type of car should be considered. Since in Cleveland pay-enter cars are used almost exclusively, the short circuiting switch is always within easy reach of the conductor stationed at the fare box and a burn-out in the car will not cause the lamps to be extinguished for more than a few seconds. If on the other hand the type of car is such that the conductor is not always at the same place, there is surely an advantage in having two circuits.

Mr. R. B. Ely: Within the past two or three years a number of papers have been presented on car lighting. One of these has advocated a system by which the light would be directed downward and forward, the light source being semi-concealed. Such a system would be an improvement over the present method of lighting the near-side car. New cars of this type are fully equipped with illuminated signs, illuminated steps, etc. The lighting installation consists of bare lamps placed along both sides over the seats. A semi-concealed system of lighting could possibly be used to advantage in this type of car.

Mr. J. B. Jackson: There is one item that I believe should be brought out more clearly in a cost analysis and that is first cost of equipment. This is a point which is of great importance to the street railway company and one which will be the principal consideration in changing the lighting equipment in present cars. It seems as though Mr. Hibben's cost of $7.00 per car is rather low as that would indicate a cost of $1.17 per unit for the six-unit equipment. I believe with the special holders required, the simplest equipment possible, *i. e.* holder, socket and reflector, could not be installed for much less than $2.50 per unit. This will make a slight increase in the last item of the cost analysis Table V. I would also suggest that the words "per year" be added to the item making it read "estimated expense of shade equipment per year."

Mr. S. G. Hibben (In reply): Concerning shadows, referred to by Mr. Porter, I have in mind one case where the objection to lighting with the center-deck units was put forth with the effect that a standing passenger would shield a seated pas-

senger, particularly if the passenger were seated on a longitudinal seat. In a brief investigation I found that there are ordinarily no grounds for such an objection. The light from the units at one side or the other of the standing passenger will give sufficient illumination so that there will be no sharp shadows on the seated passengers.

Formerly the proposition has been advanced that center deck units would not light the advertising cards. In actual practise the center of the light sources, if this type of unit were used, (referring to the fixture that projects entirely below the deck) would be 6 or 7 inches below the car ceiling, and there would be full illumination of all sides. In fact in all cases that I have seen, one is better able to read these cards, and with more comfort. One can hardly see at all the sign that is directly behind a bare lamp on the edge of the half deck.

Mr. Harrison brought out the point that on certain cars perhaps the conductor would not be within reach of the selector switch. In that case one solution might be to place the switch in the motorman's end of the car (if it were not of the double-end type) so the motorman would always be able to quite conveniently turn it.

Mr. Ely brought out the fact, and a rather surprising fact it is, that a large number of cars have improvements in heating and ventilation and illuminated signs and headlights, while as yet not much attention has been given to improving the illumination between bulkheads.

I will not enter into any lengthy discussion with some of these lamp men, for I believe they will themselves wish to reconsider or qualify the remarks as to the use of unshaded lamps. I advocate reflectors because in the first place I believe that through their use they will pay for themselves. It is purely a matter of economics, because if a reflector can increase the useful light, as it certainly can in most cases, it follows that the wattage may be reduced, and that brings about a saving that will more than pay for the added expense of the reflectors and their maintenance.

Regarding Mr. Jackson's statement concerning the costs of units,—possibly these figures of the first cost of $7,000—about

$7.00 per car—are a little bit low at the present prices of these units. The price of these will drop somewhat, as their use is extended. The cost will run about $1.17 per unit for the fixture and shade. I do not consider the installation cost a factor, since the wiring will be about as expensive for the large number of the old units, as for the less number of new units.

CHURCH LIGHTING.*

BY ROBERT B. ELY.

Synopsis: This paper discusses some of the problems encountered in the lighting of churches. It outlines briefly some requirements of certain parts of churches of different denominations. Views of typical interiors are given.

I. STRUCTURE.

In discussing the illumination of churches it may be apropos to give a few facts concerning the history of the early ecclesiastical structures as places of Christian worship.

The structures were not copied from either the Heathen or Jewish temples, but from a combination hall of justice and a market place, which was called a basilica by the ancients. The rites of heathendom were performed almost exclusively by the priest, and the temples were lighted only by the daylight that came through the doorways or interior courts, or by a few lamps that burned around the image of the God. The temple was not regarded as an assembly room for worshippers, but only as an abode of the God. Thus the dark and mysterious temples were unsuited for religious services, in which the people were to participate. Although the basilica served its purpose as a place of worship there was little or no significance in the structure to awaken Christian sentiment. The Christians from an early period used the cross as a sacred emblem, and in their endeavor to indicate their allegiance to the author of their salvation they modified their structures to the form of the cross; both the Latin and Greek crosses were followed. In either case the arms at right angles and directly opposite each other, cut it across, and were given the name of transepts. Over the point of intersection of the transepts, the body of the cross, a central tower or spire was frequently erected. Beyond the galilee or entrance chapel, or in some instances the entrance door to the transepts, was the nave. If there were no transepts the nave would extend from the choir to the principal entrances, but would not include the aisles. Side aisles frequently continued along the transepts, thus running around the whole church; sometimes there were double aisles to the nave. Beyond the

* A paper read at the seventh annual convention of the Illuminating Engineering Society, Pittsburgh, Pa., September 22-26, 1913.

transepts was the chapel or chancel, in which was situated the altar; sometimes there were several altars. Side chapels will sometimes be found on the side aisles.

The early Christian churches were lighted by daylight through the construction of a clear story.

MODERN CHURCHES.

There are scarcely two churches alike in structure although there is often a similarity of the plans of churches of the same denomination. For example, the Roman Catholic Church has generally adopted the Italian Renaissance and the Episcopal the English Gothic. But there are comparatively few classic examples in existence; most of the churches of the present day are modern adaptations of several styles of architecture. The material used in building construction and the building law requirements have made it necessary to depart from the purely classic styles in order to provide for fire-proofing and other construction details; so that one no longer sees a style or order in its true proportions. The endeavors of an architect, therefore, are not strictly along the lines of what has gone before. He usually attempts to work the adaptation of one of the various styles of architecture into a pleasing ensemble.

Any building set apart for religious services is termed a church, excepting those buildings of smaller dimensions, which are called chapels.

The Gothic style of architecture predominates in the construction of present day churches. This style is considered one of the noblest and most complete in architectural design. Its distinctive features are the Gothic pointed arch, the tendency toward vertical lines, deep mouldings on columns, capitals, etc., and decorations derived from various kinds of foliage. The towers are frequently square at the base and terminate with lofty spires richly decorated. The hammer beams and pendants are also among the chief features. But in general the modern churches are adaptations of the French and Italian Renaissance.

Intensity of Light.—In considering the quantitative values of the illumination in the church, experience has shown that it is inadvisable to stipulate a certain intensity of light for the auditorium, the sanctuary or chancel. It is advisable, however, to

Fig. 1.—Direct illumination of a church.

Fig. 2.—Overhead illumination in a synagogue.

Fig. 3.—Cove lighting in a church.

Fig. 4.—Indirect lighting in a church.

determine a relative ratio between the intensity of light of the chancel, and that of the main part of the church. That ratio in a number of effectively illuminated churches is about 2 to 1 or greater in favor of higher illumination in the chancel or sanctuary.

Owing to the general systems of control, particularly of electric lighting installations and the manipulation of this control, prior to the beginning of services one-half of the installation is usually in use. During the general service, in which the congregation takes part, the entire chancel and auditorium is illuminated. While the sermon is being delivered the illumination in the auditorium is usually reduced, and the chancel or such lamps that are used to illuminate the pastor and pulpit are used. The entire equipment is again used during the closing services. Provision should be made in Roman Catholic churches for illumination of the stations of the cross throughout the day and evening.

Any set calculation relative to watts per square foot is inadvisable, owing to the numerous variables found in church structure. Some churches are illuminated with an energy consumption of 0.3 of a watt per square foot of floor area, while others require as high as 2.5 watts per square foot, both installations being considered good examples.

There is, no doubt, greater intensity of illumination in the newer and reconstructed installations of churches; yet the variation in intensity of illumination is comparatively wide.

Commercial factors such as costs of installation and operation present themselves in all but a few instances, and tend to determine the character and intensity of the installation to a great extent. A very elaborate lighting equipment can be designed, but unless the bearing of the commercial factors of the case has been determined, the chances are that the plan will be discarded.

In the illuminating engineering work of the Philadelphia Electric Company a very broad policy permits the lighting specialist to draw up plans and specifications that are guided largely in each case by the church officials, or architect. The company aims to present a proposition that will be in keeping with the architecture, effective in results from an illumination stand-point, and economical in operation. The specialist treats the proposition in an unbiased manner. He is permitted to specify any system, shades, reflectors or reflecting devices,

which in his judgment will meet the conditions of a given case. Due attention is also paid to possible emergency lighting by gas units.

It may be of interest to mention some of the demands and tendencies of the clergymen and architects in such cases. In Philadelphia many architects have presented their plans to the company with instructions to lay out an indirect lighting proposition. In numerous instances where a direct lighting system has been laid out by the architect, the church authorities have brought their plans to the company to have estimates furnished for indirect lighting, in spite of the architect's drawn plans. There has been practically no call for semi-indirect lighting, but plans for semi-indirect lighting have been drawn and recommended where, in the opinion of the lighting specialist, the conditions were more favorable for this method of lighting.

Lighting Systems.—Direct lighting having been used to the greatest extent still predominates. This is largely due to the architects, who seem to be more familiar with this method of lighting. (Fig. 1.)

There is a tendency, however, in favor of indirect lighting, or a concealed direct lighting system.

The semi-indirect system has not been adopted to any extent, owing to the greater cost of translucent glass bowls of large dimensions, and the greater installation costs.

Direct lighting systems have been installed more generally, due to lower installation and operating costs, the influence of the architect, and the lack of information pertaining to lighting matters on the part of the general public.

I do not mean to favor any particular method of lighting; the foregoing statements are based on installations that have been made recently.

It is not at all unusual to see new buildings and churches equipped in a manner at variance with good practice, simply because the architects plans were drawn and the client had entire confidence in the architect. Generally architects will co-operate with the illuminating engineer but this is not always the case.

Fig. 5.—Altar illuminated with tungsten-filament lamps.

Fig. 6.—An electric church sign.

Fig. 7.—Sign over church entrance.

Fig. 8.—An illuminated bulletin board.

Fig. 9.—An Illuminated box sign.

Fig. 10.—Lighted entrance to church.

General Requirements (*Auditorium*).—There are some general rules that should be followed, relative to the illumination of the church auditorium.

No light sources should be within the line of vision.

All lamps in any system of illumination should be hung sufficiently high, so they will not obstruct the view of those in the gallery of the church.

No fixtures should be so located that they will detract from the architectural features.

The intrinsic brilliancy of all light sources visible from any point should be reduced, by frosting or other means.

Hymn boards should be illuminated by a concealed source.

Chancel.—Generally in the construction of the chancel one or more windows or sky lights are provided for daylight illumination of the chancel, thereby making this section of the church lighter by comparison than the main body of the church. With artificial illumination this effect may often be obtained more readily and more effectively.

In formulating a plan or method of lighting the chancel, or sanctuary, the construction of the interior of the chancel will frequently demand special apparatus, reflectors and lamps, in order to obtain effective results. A chancel arch will greatly facilitate the installation of lamps and reflectors, but when there is no arch, it is more difficult to place the lamps and reflectors to direct the light to the best advantage and avoid sharp shadows. Such equipment when placed at a great height should be so arranged that it can be lowered for renewal and cleaning purposes. But owing to the installation costs lighting units are more often located in a permanent manner behind the arch and renewals are made by the use of extension ladders.

Altars.—The use of decorative altar illumination is increasing. Electric imitation candles are being used in many churches. The lighting of tabernacle niches as well as the outlining of altars is being done quite successfully by the use of low voltage lamps.

A sign lighting transformer is often installed and receptacles

provided at various points on the altar, together with the permanent equipment, so that small electric bulb signs and emblems may be readily connected. The cost of such an installation is more or less offset by the low operating costs of the equipment. For instance in the candelabrum in Fig. 5 there were 100 8-candle-power 34-watt carbon lamps operating at a cost of about 34c. an hour. They were not used, except for special services, on account of the cost of operation. Upon installing a sign lighting low voltage transformer and 5-watt tungsten lamps the cost was reduced to about 5c. per hour. This resulted in greater use of the equipment. Of course the illumination was reduced, but this was offset by the installation of two trough reflectors with tungsten lamps behind the sanctuary columns.

On account of the tendency in recent years to increase the illumination in the body of the church it is necessary to increase the illumination in the sanctuary to make a noticeable difference in the intensity of the light in the two sections of the church.

The depth of some of the chancels is fairly great and in order to increase the illumination on the altar and reredos it is necessary to concentrate the light from a source more or less localized.

Apparatus and Fixtures, etc.—The use of dimmers in the church is becoming more general. In some Episcopal churches they are placed on a circuit of imitation candles. As the choir procession enters the chancel, the lamps are gradually brought to full brilliancy. In some of the Catholic churches dimmers are connected to the circuits of the church auditorium and sanctuary for use during special services.

The question of appropriate fixtures is an important one. The illuminating engineer should have a knowledge of decoration and ornamentation, for he is often called upon to not only plan the outlets for a lighting scheme, but to select the fixtures. In the case of some of the more novel schemes of illumination, he is obliged to design fixtures to meet unusual conditions. This means that he must be familiar with the different orders of architectural design. The illuminating engineer should study harmony of design, and particularly the effect of light and shadow on architectural ornaments.

There have been many apparent reasons given for copying

ancient lamps and light sources to carry out certain styles of architecture. In carrying out such designs of fixture and lighting units, the units have frequently been so exposed and located in such a manner as to be distressing if not harmful to the eyes. Therefore, novel and unusual methods may be inaugurated in designing the illumination for the church with due regard for ritualistic symbolism.

When the illuminating engineer attempts to effect new and unusual methods of lighting churches he should of course be familiar with the orders of architecture, and ornament, so that he will be able to so design the lighting installation that some of the architectural features of the building may be brought out by light and shadow without distorting their appearance.

The candle is used in the services of the Roman Catholic, Episcopal (high), Lutheran and German Lutheran churches. It is given more prominence in the ceremonies of the Roman Catholic church than in the others.

In the Catholic churches the altar is the main feature to be considered. A rubric of the church requires the use of wax candles for various services. However, in numerous instances some of the candles that are still in use can be replaced by either gas or electric imitation candles to greater advantage, and this will result in a more effective appearance.

The lighting specialist should know when and how candles are used in religious services, their advantages and disadvantages. The mellow glow of the candle with the low intrinsic brilliancy of its flame is pleasing, aside from the flicker. Whether the flickering of the candles for religious purposes is a distracting feature, or whether the candles are more effective under such condition is probably an open question. There are certain times, particularly on holy and feast days, when the altar is illuminated to a greater extent than for ordinary services.

The candle has some disadvantages that cannot be overlooked, such as flicker, fire hazard, and labor required to maintain the proper appearance of the candle and fixture. Therefore, all candles that are used in addition to those required by the rubrics of the church may be replaced with electric imitation candles, or gas burners.

Organs.—The lighting of the keyboard and pedals and interior of the organ frequently present some difficulty, owing to the location of the keyboard and the necessity for concealing the light source from the eyes of the congregation. Some lighting installations have been marred by the glare of an exposed light source supplying the illumination for the music rack and keyboard, and by the lamps that are used to illuminate the choir when it is located in the front of the church.

It is customary to provide a portable lamp or extension bracket for the music rack connected to a live circuit to permit the organist to illuminate his music during his rehearsal on weekdays without using a number of lamps.

Illumination for the choir, when it is located in the gallery, can be provided by brackets or ornamental standards in direct lighting installations.

A lamp equipped with a metal reflector located under the keyboard is frequently recommended for the illumination of the pedals.

ADVERTISING AND EXTERIOR ILLUMINATION.

Church advertising is being indulged in. A number of churches in Philadelphia purchase half a page of the newspapers on Saturday of each week, and announce subjects, relative to church benefits and aims, that are to the interest of the community. This advanced step towards business management of the church has greatly assisted in the introduction of exterior illumination of the church and the adoption of the electric sign. Numerous churches have installed both illuminated and straight electric signs. Some of these signs contain large numbers of lamps.

Greater attention should be paid by the manufacturer of electric signs to their designs. The sign should be of a design somewhat similar to the architecture, and may be improved by the use of Gothic or old English letters. The use of these letters in themselves would give to the sign a certain dignity that is not obtained with the block letters that are in general use. But the legibility of a sign might thus be somewhat sacrificed. However, this is a detail which should receive more favorable consideration from those interested in the introduction of signs.

The illuminated cross on the steeple of the church is very

effective, and can be seen at a great distance. There is no doubt that it is an advertiser of the church.

Mr. A. Larney describes in an article on the erection of an illuminated cross, a very interesting method of installing the lamps:

> Lamps are screwed into the receptacles mounted on three flexible belts equipped with a series of rope guides and pulleys, by means of which the installation can be lowered from the cross down into the interior of the spire. In this way lamp renewals can be made without the assistance of a steeple-jack or building a scaffold.

Fig. 11.—Church exterior showing lighting standards.

In spite of the many drawbacks and difficulties involved in erection and maintenance of such crosses, a great many of them have been installed. The renewal of lamps has, in numerous instances, been the work of a steeple-jack, but the construction, as described by Mr. Larney, may be possible in numerous in-

stances, and should lead to greater use of this method of advertising the church.

The use of lamp posts to improve the illumination of sidewalks about the exterior of the building tends to make the churches stand out to better advantage, and to encourage attendance, and adds to the safety of the pedestrians when the sidewalks are covered with snow or ice.

Bulletin Boards.—Some churches have bulletin boards that may be illuminated at night. Special features of this kind add to the value of church lighting. A bulletin board of this kind can be illuminated every night at very small expense to the church.

The illumination of clock-dials is a feature that should not be overlooked, for it adds to the nightly use of light by the church, and acts as a constant reminder to those traveling in the vicinity.

Entrance to Church.—Entrance lighting is important. It not only illuminates the stairway and the approach to the church, but indicates to the general public when illuminated that services are being held. Ornamental brackets containing lamps are used extensively for such lighting. Often the arch of the entrance is outlined with a series of lamps.

The importance of proper church lighting is too often minimized by pastors, church boards, and those who have to do with church management. Ordinary business methods are about as important in the management of the church as they are in a mercantile establishment; and perhaps more important because the objects to be obtained in the case of the church are so much more vital to the entire community. It is the business of those who manage church property to see to it that attendance at church services shall reach a maximum, and remain there; and yet it is surprising how little is done to make our churches inviting, cheerful and comfortable. There is no single factor, which will accomplish this result so surely, and at such small initial expense as a scientifically designed system of lighting.

Every one knows that any illumination which produces eyestrain or fatigue among the congregation is a positive force tending to reduce the interest of those attending church services. Proprietors of places of amusement discovered this fact many years

ago, and now-a-days they look upon the use of light as a positive necessity.

From every standpoint good illumination is just as important in the church as it is in the place of amusement. Emphasis is laid upon the comparative methods employed by places of amusement and churches in the matter of making their audiences comfortable. There is nothing in religion which teaches that those who attend church services should be made uncomfortable, and yet lack of forethought upon the part of those responsible too often makes attendance at church services a positive source of distress for those whose eyes are not strong or cannot stand the eye-strain caused by poor illumination.

DISCUSSION.

MR. J. R. CRAVATH: I think it is very gratifying that one member here in one year is able to present so many comparatively excellent examples of church illumination. I wish to call your attention to some of the future possibilities of cove lighting with the new helical filament tubular lamps. The cove lighting shown by Mr. Ely shows some undesirable characteristics of cove lighting as it has necessarily been carried out in the past; that is an excessive amount of light close around the curve with too little farther away. The new tubular lamp with the helical filament is going to make it possible to control the light much better for cove lighting and without some of those bad effects that have heretofore been inherent in it.

Fig. 1, shows a church with paintings on the ceiling. I am not prepared to say that there is any better way of lighting that particular church, but I simply want to call your attention to the fact that any exposed lights are going to hide the paintings to a certain extent, and that this fact must be borne in mind by the architect when he is designing the church. If it is so designed that it must necessarily be lighted by some exposed lighting unit, the effect of the paintings will be lost at night.

MR. A. L. POWELL: Church lighting forms an extremely interesting subject and an observation of most of the existing installations shows that there is still a great deal of work to be done.

By way of supplementing the data included in the paper, the following remarks may be of value.

As a result of a number of tests, it has been found that an average intensity of 1.5 foot-candles on a 3-foot horizontal plane, is very satisfactory for church lighting, where proper precautions have been taken to shield the eyes from glare.

Semi-indirect illumination is quite feasible and the cost has not been high. There are simple designs in pressed opalescent glass bowls whch give excellent results, and the cost is very slight. The use of white leaded glass semi-indirect units is a very promising innovation, and it is possible to design units along Gothic or Renaissance lines, so that they will harmonize excellently with the church architecture. I have in mind a church in North Adams, Mass., where there are large fixtures of white leaded glass of Gothic design 6 feet in diameter which hang 15 feet from the peak of the arch. Each fixture has 3 150-watt and 3 250-watt tungsten filament lamps. Only a few built up units of this type are necessary for a given space and consequently the wiring cost may be reduced considerably.

This white glass has been utilized for direct lighting. An asymmetrical reflector used in the Buffalo General Electric Company's building, was described* by Mr. Ryan, at last year's convention. The design was slightly modified and the equipment used for a church which had a fan-shaped roof that reached a maximum height above the pulpit. Outlets were located on the ribs and the fixtures hung to direct the maximum light toward the front. There was sufficient diffused light transmitted through the glass to light the balcony, and the main portion was lighted by the reflected light.

The term "line of vision" is mentioned in the paper, and that brings to mind the question: What is the line of vision? As a homely illustration, one may note that the ladies of the church often wonder why the gentlemen go to sleep so much more readily than they do at a service. It has been my experience that there is usually, within the angles of vision, a number of bare or improperly shielded light sources, which shine directly into my eyes. The ladies have their hats on while in church,

* TRANS. I. E. S., Vol. VII, No. 8 (Nov., 1912), p. 597.

and hence, their eyes are more completely protected, and drowsiness does not result as readily.

As regards the designing of special reflectors for chancel lighting, I may say that we have had very good success in lighting chancels of the arch type, by using angle steel or glass reflectors, giving asymmetric curves. In the chancel without the arch, there are quite often Corinthian columns or similar structures on both sides, and by using the tubular type lamp with a cylindrical or trough reflector, to direct the light to the opposite wall rather than to the adjacent wall, as in cove lighting, good results have been obtained. When lighted from the side rather than from overhead most chancels appear better illuminated because the shadow effects are softened.

The lighting in the choir loft is often very annoying, for it is usually accomplished by a number of small lamps with diffusing shades which are in the line of vision. In some churches where it has been impossible to install lamps within the interior of the organ, or on the music racks, the opaque, bowl steel reflector, with its exterior painted to harmonize with the woodwork, has been used.

Window lighting from the exterior has been very satisfactorily accomplished by the use of asymmetrical, weatherproof type steel reflectors and regular lamps, or the tubular type lamp and small reflectors arranged to evenly illuminate the entire window surface.

PROF. F. C. CALDWELL: The point was brought out that the deck lighting as shown on Fig. 2, does not give suitable lighting for the upper part of the room. This is perhaps due to the fact that the deck is somewhat recessed—the glass should be kept down as near the ceiling as possible. In deck lighting it is important that a glass of good transmission efficiency be used. Ordinary skylight glass is very well for daylight, but seriously interferes with the efficiency of a lighting system. Even where economy is not of prime importance the best results can usually be obtained by putting money into good glass rather than into additional power.

MR. R. F. PIERCE: There were one or two points brought out in these two papers that are of especial interest in connection with the paper presented yesterday by Dr. Ferree. There seems

to be a considerable movement in the direction of reducing the brightness of surfaces within the range of vision. This is shown by the popularity of direct and semi-indirect systems of lighting. In churches, particularly, people are quite sensitive to the aggravation produced by glaring light sources, and the fact that they have often resorted to the so-called indirect system of lighting is excellent evidence that our commercial glassware which, the reflector manufacturer tells us effectively shades the lamp and reduces the glare, really does comparatively little to that end. The results given in Dr. Ferree's paper yesterday indicate that reducing surface brightness of reflectors to the extent commonly found in commercial types is not sufficient to make the surface much less objectionable from a standpoint of depreciation in eye efficiency than the bare lamp. We would, however, not be justified in concluding that indirect lighting as such is responsible for the results obtained by Dr. Ferree. If we use a direct lighting system in which the enclosing glassware forms the whole ceiling of the room as shown in Fig. 2 in Mr. Ely's paper and in the installation described by Mr. Kingsbury, we have an installation in which the surface brightness of the glassware is no higher than that of the ceiling in an indirect lighting system to produce the same illumination, and we would certainly not expect any different results as regards the efficiency of the eye. On the other hand, if we use an indirect reflector concentrating the light on a very small spot on the ceiling and producing a surface brightness in the neighborhood of two or three candle-power per square inch, we would have a condition that we would expect to be quite as annoying and quite as unfavorable to the efficiency of the eye as a direct lighting system in which a similar distribution of surface brightness occurred. It appears that the principal factor is the brightness and area of the illuminated surfaces, and it is immaterial whether a certain distribution is obtained by "direct" or "indirect" means.

One serious drawback to the indirect system is the reversal of the natural order of intensities. Under daylight, the higher intensities are found at the lower levels, and the lower intensities at the upper levels. This condition is reversed with indirect lighting on account of the fact that the reflecting surfaces are

generally diffusing, each element giving a circular distribution curve, and it is practically impossible to avoid illuminating the upper portions of the side walls to a higher degree than the lower portions.

This effect may be avoided in deck lighting systems, however, since the deck may be constructed of glass which, while sufficiently diffusing to reduce surface brightness, will not seriously interfere with the direction given to the light rays by the reflectors. This effect is seen in the illustration of the deck lighting systems shown by Mr. Ely.

Another important consideration in church lighting which frequently militates against the employment of indirect lighting is that of esthetic effect. The prevailing type of church architecture is Gothic, in which it is the purpose of the architect to allow the high, pointed arches to remain in comparative darkness. When the indirect system of lighting is used, the brilliant illumination in this portion of the building entirely destroys the effect which the architect strived to produce. Some particularly atrocious examples of a disregard for architectural considerations by the application of indirect lighting to Gothic interiors have been found in recent installations, and are excellent examples of what good illumination should not be.

In the installation described by Mr. Kingsbury, use was made of what might be termed a semi-indirect lighting system in which the wall is used as a reflecting surface instead of the ceiling. This is quite similar to one of the installations described by Dr. Ives in reporting his experiments on the approximation of daylight distribution in residence interiors. As I have not had an opportunity to observe the results of lighting of this character, I am unable to comment upon it; but I think it presents a problem worthy of more extended investigation.

MR. J. R. CRAVATH: In regard to Fig. 2 in Mr. Ely's paper, I don't agree with Mr. Pierce that it represents an ideal condition, because just as Mr. Luckiesh has said, the contrast of the brightness within the range of vision is the very important point. In this case if we are to judge from the photograph (which, however, may not represent things just as they are), we have

a very decided contrast between the brightness of the skylight and the brightness of the ceiling and bright surroundings. Now, that is probably about the best way that particular installation could be lighted, but it does not illustrate an ideal condition, because, that contrast must be annoying. Any kind of violent contrast of surface brightness which one must face constantly cannot fail to be annoying.

MR. T. J. LITLE, JR.: In a number of the installations described by Mr. Ely, particularly the one shown in Fig. 2, it would appear that mural decorations on the side-walls and ceilings are not properly lighted. The decorations referred to are usually very costly and in the lighting of such a building the illumination must not only be sufficient for reading purposes but must be of a character which will properly bring out the decoration above referred to.

In reference to Fig. 1, I should say that a person sitting halfway back in the church would see at least half of the fixtures. In other words, the light sources would be within his range of vision. I think the lighting of a church should be so arranged that the lamps would be out of the range of sight. The light would probably be in the speaker's eyes, but this could not be avoided. At any rate, he is more apt to look down upon the congregation and with the lamps hung high in the church they would not be so apt to annoy him, and even if they did, from the standpoint of the greatest good to the greatest number such an arrangement would be considered preferable.

Why should the lighting of a church building be considered so differently from the lighting of a theatre? In the latter case, the lamps are of necessity shining in the player's eyes. Bare lamps are never allowed to annoy the audience.

MR. E. B. ROWE: I have one or two questions to ask. One Mr. Powell has touched on in connection with the use of semi-indirect lighting. On the sixth page Mr. Ely mentions the fact that semi-indirect lighting has been recommended where the conditions were deemed very favorable. I would like as a matter of information to have him give, if he can, what he considers the conditions which are favorable to that system more than conditions which are not.

In regard to the use of light units on the chancel side of beams, etc., it occurred to me that there is one disadvantage inherent in that type of lighting and that is the glare in the eyes of the pastor and the choir if it is on the chancel end of the nave; perhaps he may have some information to give us as to whether there have been any objections made from that standpoint. That is an excellent method I think of obtaining an efficient illumination very similar to direct lighting.

It occurred to me with regard to the lighting of croses on the exterior of the church, which sometimes have to be located in inaccessible points, that use might be made of the new concentrated filament incandescent lamp in parabolic reflectors, so that there would be no need of ever going up to the cross itself.

Mr. Luckiesh: I want to supplement one of the points brought out by Mr. Pierce by describing one of the most annoying cases of glare I ever experienced. This installation is in one of the modern auditoriums in Cleveland which was installed by an architect who I know has little use for an illuminating engineer. The auditorium proper is lighted from beautiful indirect fixtures. The pulpit however is lighted by concealed sources as in Fig. 2, of Mr. Ely's paper. When the pulpit alone is lighted the contrast between its bright background and the dark surroundings causes a most annoying glare. This brings out the point that glare is not always due to high brightness.

Mr. G. H. Stickney: The author is to be congratulated on having such a large number of successful church lighting installations. There is probably no other class of lighting problem which the illuminating engineer approaches with more trepidation, since the artistic requirement in church lighting is so predominant that the engineer, unless he can fully co-operate with the architect, is at a tremendous disadvantage.

One of the most interesting problems in church lighting which I have ever handled, and one which illustrates a novel method which I have not seen used elsewhere, was in a large Gothic cathedral in Montreal. This is a magnificent building erected about 100 years ago. The main portion consists of three Gothic naves, the center one being about 100 feet high. As the ceiling is dark finish, the usual indirect lighting would have been unsuit-

able, although the equipment actually used might be classed as indirect. In the previous installation fixtures were suported from the backs of the seats and fairly brilliant light sources located about 7 or 8 feet above the floor in such a manner as to detract from the general view, especially of worshippers in the rear seats. In the upper part of the building along each side of the central nave was a line of windows which opened into a covered space between the nave and the roof. Prismatic glass was inserted in these windows and large tungsten filament lamps arranged behind them, each equipped with a metal reflector so as to direct the light through the window. The prism glass deflected the light downward, and it was possible, by adjusting the height of the lamps with regard to the windows, to control the distribution of light and proportion it properly between the upper and lower portions of the church. The energy consumption was a little over one watt per square foot of floor area. While I never had an opportunity of seeing the completed installation, it has been reported as producing a most pleasing effect, and that it is possible to read in any part of the church.

Mr. R. B. Ely: In answer to Mr. Cravath's remark about the installation in which the paintings appear—In that case we used a cluster of tungsten lamps equipped with distributing type reflectors of light opal glass to get diffusion, which was attached to a rope and pulled up from the floor to the ceiling; it was placed at various heights until we got that height at which the paintings could be seen to best advantage. By increasing the intensity (various sizes of lamps were tried) so as to get more brilliancy all over the church, it was found that the paintings could be seen more readily with a higher intensity than under the lower intensity.

Mr. Powell touched on the intensity of illumination. It should range, he stated, from ¾ to 1.5 foot-candles. However, some churches, particularly Catholic churches, have to be lighted as brilliantly as possible at certain times, Christmas and Easter for example. Sufficient equipment should be installed to provide the extra illumination required on such occasions.

Mr. Powell spoke about the question of lamps being in the

line of vision, and answered it himself. I think we can all tell when a lamp is annoying or whether it is in the line of vision.

Reference was made to special reflectors for chancel illumination. There have been cases where it has been desirable to illuminate the chancel more brilliantly than other sections of the church, to bring out that part of the church. And in such cases it is desirable to cut off the illumination from the lower and top sides of fixtures to get that effect. We have in some instances made special corrugated glass reflectors with definite cut-off points.

Reference has also been made to putting lamps behind Corinthian columns, with tubular lamps. We were called in on a case that had such equipment, simply because the desired results could not be obtained. The church panels which had been installed at a cost of something like $2,000 were entirely flat with this method of lighting; no irridescence from the tile panel was to be had. Search-light lamps with parabolic reflectors were used to direct light on these panels until the angle where the irridescence would appear to the congregation was found. Then equipments were installed at those points, and the lighting was found to be very effective.

In window lighting, as a rule, the main window or the most beautiful window frequently appears at the rear of the church. And the equipment for the gallery is generally located in that section. With indirect and semi-indirect systems the fixture for this portion of the church is usually located so that it will illuminate that window to the best advantage, and at the same time provide illumination for the gallery.

Regarding Mr. Caldwell's question about the introduction of semi-indirect lighting—there are quite a number of cheap bowls for semi-indirect light, but when one is dealing with a church where generally very large units have to be used, I have invariably found the cost to be greater than that of other types. It doesn't make so much difference if it is a new installation, that is in a new building being erected; the cost is then not such a factor. But if it is an old installation and there is competition it is a factor.

Mr. Pierce referred to Fig. 2. The effect is not as it appears in the photograph. There is considerable diffusion from the

walls which are very light buff; and the paneling of the ceiling may be seen readily. It is not dark, as it appears in this photograph; the darkness is probably due to long exposure in taking the picture.

Mr. Luckiesh referred to the glare from the chancel. When the rest of the lights in the auditorium are turned out we try as far as possible to get a theatrical appearance, you might say; that is, to concentrate the light on the pastor, as you would in a theater concentrate the light on the actors. And frequently where there is a very light background a portion of the lights are turned out, excepting those that would tend to show the pastor.

Mr. Litle commented on the same effect as produced in Fig. 2, and as to reflection from walls, ceilings and decorations. These are all well brought out under that installation. When planning a lighting system for a church we consider the decorations. They constitute a feature which should be properly illuminated.

I believe, as Mr. Marks said yesterday, that "any system of illumination can be made very effective," and in all church installations we are largely governed by the architectural considerations and the character of walls and ceilings.

SOME STUDIES IN ACCURACY OF PHOTOMETRY.*

BY EVAN J. EDWARDS AND WARD HARRISON.

Synopsis: Five separate investigations are reported in this paper: I—Relative accuracy of Bunsen and Lummer-Brodhun devices. This test involving several thousand readings showed the sensitivity, expressed in average deviation, to be 0.4 per cent. for Lummer-Brodhun as compared with 1.5 per cent. for the Bunsen. II—Magnitude of error due to parallelism of rays, in the photometry of reflector sources. The results of tests on typical reflectors for general illumination purposes show the errors to be negligible. III—Method of investigating adjustment error; and the calibration of portable photometers. This method consists in taking photometer readings for various distances from a working standard lamp and analyzing the results by reducing the relation to a straight line function. The constant of the photometer is obtained from the slope, and working standard intensity. IV—Errors in illumination measurements due to failure of test plate to obey the cosine law. Discrepancies between measured and calculated values of illumination are fully accounted for by this investigation. The average error of the plates investigated was found to be over 10 per cent. at 45°. Computations show that the photometer results for an average installation are about 12 per cent. low. V—Method of obtaining and recording distribution data. A so-called thousand lumen basis of drawing distribution curves is proposed, in order to avoid error and confusion in comparing reflector units. On this basis zonal lumen values are instantly convertible to per cent. of total and intensity values to per cent. of horizontal for the bare lamp. By using a single multiplying factor all values can be corrected to current lamp efficiencies.

Many investigations which have to do with accuracy in photometry have been made in the laboratories with which the authors of this paper are identified. These investigations have served their purpose as far as the particular laboratory is concerned, but in some instances have not been reported. It is believed that brief reviews of the more important ones will prove useful to the members of the Illuminating Engineering Society.

This paper, then, is of the nature of a report on five separate investigations.

* A paper read at the seventh annual convention of the Illuminating Engineering Society, Pittsburgh, Pa., September 22-26, 1913.

I—Relative accuracy of Bunsen and Lummer-Brodhun devices.

II—Magnitude of error due to parallelism of rays, in the photometry of reflector sources.

III—Method of investigating adjustment error; and the calibration of portable photometers.

IV—Errors in illumination measurements due to failure of test plate to obey the cosine law.

V.—Method of obtaining and recording distribution data.

No attempt is made to connect the various investigations, although it will be seen that the method used in Investigation 2, suggested the procedure of Investigation 3.

I. RELATIVE ACCURACY OF BUNSEN AND LUMMER-BRODHUN DEVICES.

There is at present little question as to the order of sensitivity of the common forms of photometric devices. The quantitative results of an extended test to obtain relative accuracy values of the Bunsen and Lummer-Brodhun devices, which resulted in a decision to discard all Bunsen apparatus in favor of Lummer-Brodhun, may, however, be of value.

About five thousand readings extending over a period of three months were taken in order to establish beyond question the relative accuracies of the two devices under the particular conditions involved. The Bunsen photometer used was of the regular type, a circular spot surrounded by a concentric field and viewed by means of two angle mirrors. The Lummer-Brodhum photometer used was of the low-contrast variety, which has been shown* to be more sensitive than the earlier high contrast type. Except for the sight box, the same photometric equipment was used for the entire test. Twenty incandescent electric lamps of various kinds and efficiencies were used, all against the same comparison lamp in order to get an idea as to the effect of color difference.

The details of the test and many interesting but less important deductions must be omitted. As an example may be cited the test on the effect of changing the shape of the Bunsen spot. It was found that a star shaped spot was easier to manipulate

* Lummer and Brodhun, *Zeitschrift fur Instrumentenkunde*, Vol. 9, p. 461.

and showed a higher sensibility although of the same order. It is sufficient here to show the condensed results for the more common type of Bunsen in the curves of Fig. 1 bearing in mind that the precision is expressed in average deviation from the mean and that ten readings were taken on each lamp with each device for each set of observations. It is seen that the Lummer-Brodhun precision is about four times as good as the Bunsen. The actual grand average for the entire test is 0.4 per cent. average deviation for the Lummer-Brodhun and 1.5 per

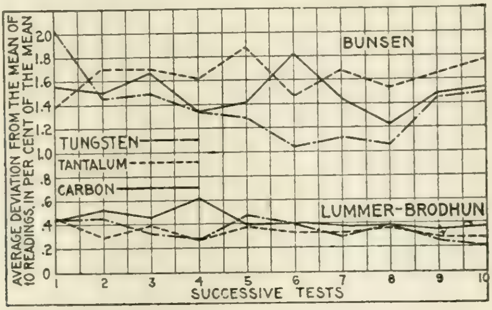


Fig. 1.—Relative accuracy of Bunsen and Lummer-Brodhun devices.

cent. for the Bunsen. No marked loss in precision results from small color differences such as with carbon against tungsten.

II. MAGNITUDE OF ERROR DUE TO PARALLELISM OF RAYS, IN THE PHOTOMETRY OF REFLECTOR SOURCES.

Many who have had occasion to calculate illumination from the distribution curves of lamps with concentrating reflectors have, no doubt, had a feeling of uncertainty as to the accuracy of their results, due to the possible parallelism of a portion of the light rays.

It would seem that where a reflector directs the rays to a considerable degree, that there would be brought about an appreciable effect of parallelism of the rays. This investigation was undertaken with the idea of obtaining a measure of this effect of parallelism in commercial types of reflector units.

In the theoretical extreme case of a parabolic reflector and a point source, the illumination at various distances would be

constant. The point source with no reflector would, of course furnish an illumination which would be strictly proportional to the reciprocal of the square of the distance. A partial parallelism, such as results from the use of a directive reflector, would be expected to bring an illumination which does not decrease with distance as much as would be given by the inverse square law.

In order to determine the magnitude of these effects, tests were conducted on a number of typical reflectors using a Weber portable photometer in such a manner as to eliminate other sources of error. The method employed depends upon the principle that when a photometer screen is balanced between two point sources of constant intensity the ratio of the distances of the two lamps from the screen is constant. Readings were first taken on a bare lamp at distances varying from 3 to 25 feet 0.914 to 7.315 m.) to serve as a test of the adjustment of the photometer, and then the bare lamp was replaced by various reflector units in turn, and readings obtained. The relation between the test and comparison lamp distances from the photometric screens is a straight line for point sources, and moreover a straight line passing through the origin. Therefore a plot of distance of the test unit against photometer reading (since a Weber photometer reads comparison lamp distance directly) serves as a complete test of the inverse square law is applied to the unit in question.

The distance of the light unit was varied by raising and lowering it, the portable photometer being set up directly beneath. Readings were taken in the direction of the axis of symmetry of the unit, since the effect should be most pronounced at this angle.

The results for several types of reflector units are summarized in the curves of Fig. 2. They are self-explanatory, both as regards quantitative results and their precision since the actual points are shown. Each point is obtained from the average of four photometer readings. The abscissae of the bare lamp, extensive and intensive curves, have been multiplied by two in order to show all curves conveniently on one sheet. Therefore,

the intercepts of the extensive and intensive curves, as drawn, show twice their actual values.

It is seen that the curves are fairly good straight lines and also that the intercept is within the body of the filament in every case.

A failure of the line to pass through the origin shows that the distance which should be used in computing illumination by the inverse square law may not be exactly the same as the distance to the center of gravity of the filament. It appears from the curves that such a discrepancy is more likely to occur than

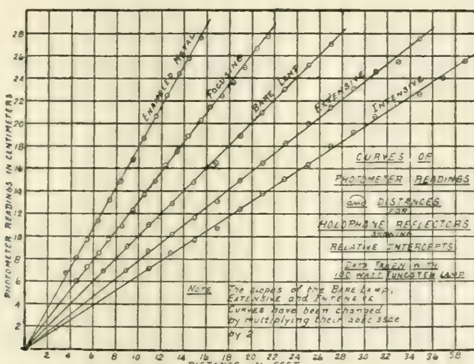


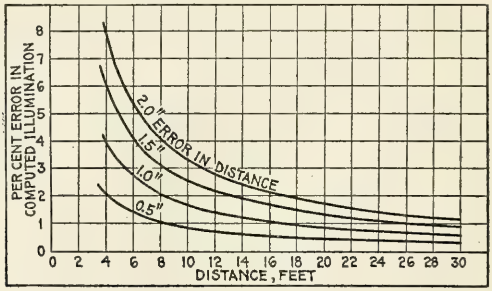
Fig. 2.—Curves of photometric readings and distances for reflectors, showing relative intercepts. Data obtained with 100-watt tungsten lamp. (The slopes of the bare lamp, extensive and intensive curves, have been changed by multiplying their abscissae by 2).

an error due to a failure of the inverse square law itself. This is shown by all the curves being straight lines having slightly different intercepts. There may be an appreciable shifting of the effective luminous center, but there is no appreciable deviation from the inverse square law.

Errors in illumination calculations due to an error in the distance used in computations is given by curves of Fig. 3. The error due to assuming the distance—that to the center of gravity of the light source—is probably less than 1 or 2 per cent. in the usual case where the unit has been photometered at the distances of about 10 or 12 feet (3.048 or 3.657 m.).

The error due to parallelism must be small, as will be seen by

reference to curves of Fig. 4. These show the effect on the graph when certain percentages of the illumination at 10 feet (3.048 m.) are assumed to be the result of parallel rays. The deviation from a straight line becomes very marked.



Fige. 3.—Curve showing errors in illumination computations resulting from error in the distance.

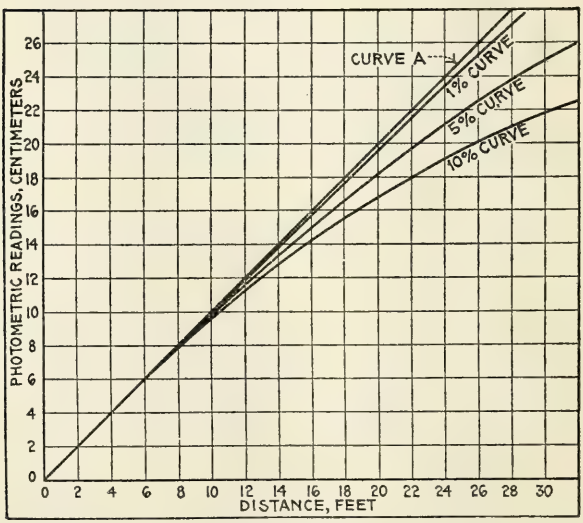


Fig. 4.—Effect of parallel rays on measurements of illumination. Curve A is one which would be obtained from the point source; other curves show effect of parallel rays for given percentages of illumination at 10 ft. distance, due to parallel component.

The results of this investigation seem to justify the conclusion that for all practical purposes illumination from general lighting units may be computed by using the inverse square

law and taking the distance as that to the center of gravity of the light source. It is unnecessary to specify the distance at which distribution curves are taken, provided, of course, that they are taken at a distance several times the greatest dimension of the unit. Also, it is unnecessary to use the term apparent candle-power in connection with the directional intensity of such reflector units as are used for ordinary illumination purposes.

III. METHOD OF INVESTIGATING ADJUSTMENT ERROR, AND THE CALIBRATION OF PORTABLE PHOTOMETERS.

The method used in the investigation of the effect of parallelism in the photometry of reflector units suggested itself as being a very good one to apply in the calibration of portable photometers. In fact, in the previous work a portable photometer was used as the photometric device, and the bare lamp test originally showed the photometer to be out of adjustment. The adjustment error was corrected by means of the data obtained on this preliminary run.

Portable photometers have a variety of means of varying the brightness of a comparison surface which is matched with the surface illuminated from the test end. The general method, here described, is applicable to all when consideration is given to the particular principle by which they work.

Consider first the type where the distance from the comparison lamp to the diffusing plate is varied, such as the regular Weber photometer.

Let I_1 = c-p. of a working standard which can be placed any distance from screen.

I_2 = c-p. of comparison lamp.

d_1 = Distance of I_1 from its diffusing plate.

d_2 = Distance of I_2 from its diffusing plate.

When a photometric balance is obtained

$$(1) \quad \frac{I_1 t_1}{d_1^2} = \frac{I_2 t_2}{d_2^2}$$

where t_1 and t_2 are respectively the transmission coefficients of the diffusing plates for I_1 and I_2.

$\frac{t_2}{t_1}$ is a constant and therefore may be placed equal to K_1 or,

$$(2) \quad \frac{I_1}{d_1^2} = K_1 \frac{I_2}{d_2^2} .$$

Since the scale of the Weber is graduated to give d_2 directly, the reading

$$(3) \quad R = d_1 \sqrt{\frac{k_1 I_2}{I_1}} .$$

Considering I_1 and I_2 constant, the relation of R and d_1 is, of course, the equation of a straight line passing through the origin.

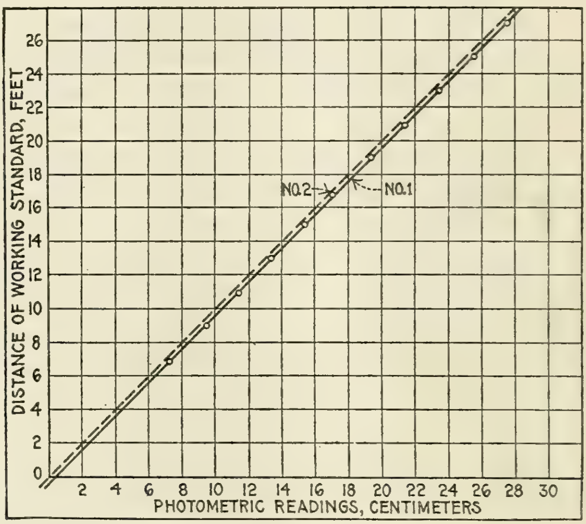


Fig. 5.—Adjustment and calibration of Weber photometric.

It is seen from equation 3 that a test run made by setting up a working standard lamp at various distances from the screen of a portable photometer serves as a complete test of the accuracy of adjustment and of scale graduation. A curved or irregular line would indicate errors such as incorrect graduation of the scale. The failure of the graph to pass through the origin indicates an error such as incorrect position of the comparison lamp. Curve 1 of Fig. 5 illustrates the manner in which incorrect position of the comparison lamp is shown by this method.

Curve 2 of Fig. 5 shows the results, as obtained, after correcting the comparison lamp position by measuring the intercept of Curve 1. It is interesting to note in this connection that the actual position required to give the zero intercept does not correspond exactly with the measured value, due, probably, to the reflection of light on the inner surface of the tube.

Letting C represent the multiplying factor, which must be applied to the reciprocal of the square of the photometer readings to obtain illumination values in foot-candles, it is seen from Equation 3 that $C = K_1 I_2$. Therefore, $C = I_1 \left(\frac{R}{d_1}\right)^2$, and it follows that the constant of the photometer is given by multiplying the intensity of the working standard by the square of the slope of the graph.

For a photometer, such as the Sharp-Millar, where the readings are made proportional to the reciprocal of the square of the distance to the comparison lamp, the equations are changed. Here the relation of d_1 and $\frac{1}{\sqrt{R}}$ should be a straight line passing through the origin. Since the slope of the line in this case is equal to $\frac{1}{\sqrt{R}d_1}$, the constant of the photometer is given by multiplying the intensity of the working standard by the square of the slope. A photometer of this kind is usually calibrated to have unity constant, so this method does not lend itself particularly well for purposes of calibration, but is very useful in testing out the adjustment of the instrument as well as the accuracy of a particular calibration. In the laboratories with which the authors are connected, special equipment is provided and tests of this kind are applied to all portable photometers at frequent intervals.

The change of constants effected by the use of absorbing screens may also be accurately determined once for all by this method. If there are a number of absorbing screens which have transmission coefficients m_1, m_2, etc., which can be used either on the test or the comparison end of the photometer, the new

constant C′ is equal to $\frac{C}{m}$ if a screen is used on the test end and Cm if used on the comparison end. The change in constant is then obtained by a calibration test with and without an absorbing screen, and the transmission coefficient is given by the ratio of the two constants thus obtained. It will, of course, remain unchanged except as affected by collection of dust or dirt.

IV. ERRORS IN ILLUMINATION MEASUREMENTS DUE TO FAILURE OF TEST PLATE TO OBEY THE COSINE LAW.

In measuring the illumination in the usual lighting installation by means of a portable photometer, the light reaches the test plate at practically all angles. A test plate which fails to obey

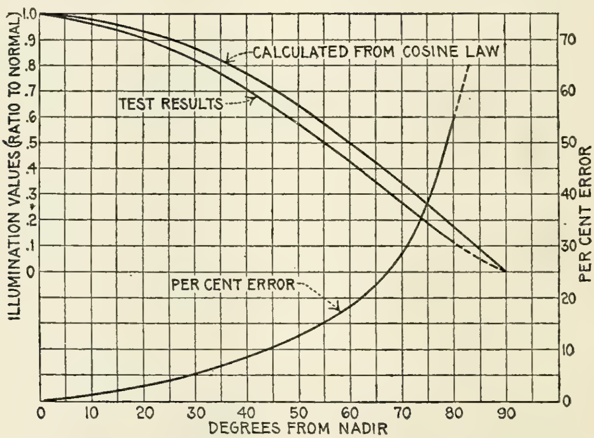


Fig. 6.—Error in photometric test plates, due to failure to conform to the consine law.

the cosine law will give proper weight to only the light which strikes it at an angle normal to it, assuming, of course, that the photometer has been calibrated in the normal. This investigation was begun after noting discrepancies between measured and calculated illumination values for several installations. The discrepancies were noted particularly where extensive-type reflectors were used.

It was rather surprising to learn that no flat plate could be found which did not show a very considerable error. It was also rather surprising to find that all the plates tested, although ob-

tained from different sources checked within 1 or 2 per cent. The complete results together with a curve showing the per cent. error are given in Fig. 6. The illumination values are given for convenience in terms of ratio to the normal.

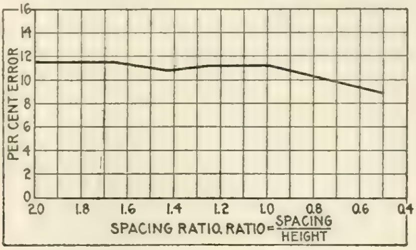


Fig. 7.—Average per cent. error in illumination values for an installation of a large number of units. (Extensive enamelled steel type on 10 ft. centers.)

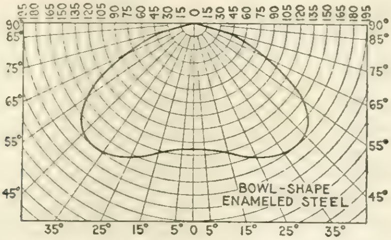


Fig. 8.—Photometric distribution curve of bowl shaped enamelled steel reflector.

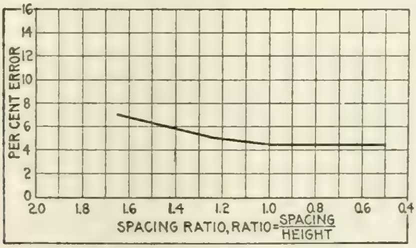


Fig. 9.—Average per cent. error in illumination values, for an installation of a large number of units. (12.in. mirrored reflectors on 10 ft. centers.

It is seen that the error at 45° is more than 10 per cent. The curves of Figs. 7, 9 and 11 are the result of laborous computations and are given as illustrations of the magnitude of the errors which are obtained with commonly used systems in large rooms. Fig. 7 is an example of extensive distribution being for bowl-

shaped enamel steel having the distribution shown in Fig. 8. Likewise, Fig. 9 is for the narrow distribution shown in Fig. 10. Fig. 11 is still another example showing the error for another type of extensive distribution shown in Fig. 12.

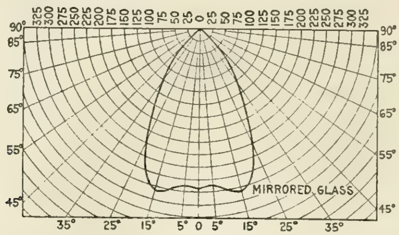


Fig. 10.— Photometric distribution curve and mirrored reflector.

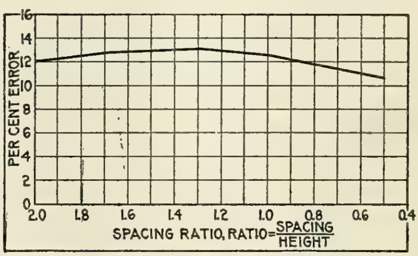


Fig. 11.— Average percent error in illumination values, anfor installation of a large number of units. (Enamelled steel dome shaped reflectors on 10 ft. centers.)

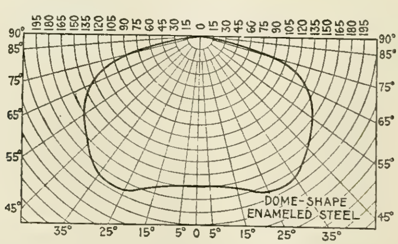


Fig. 12.—Photometric distribution curve of enamelled steel dome shaped reflector

The results of this investigation point to the conclusion that the error in making illumination readings with the average flat test plate is more than 10 per cent. in the majority of cases. The discrepancy between measured and calculated values which have

been observed are fully accounted for. For accurate work a carefully designed curved surface test plate should be used, or the proper correction should be applied where flat plates are used.

V. METHOD OF OBTAINING AND RECORDING DISTRIBUTION DATA.

Distribution curves on various reflector units are largely for

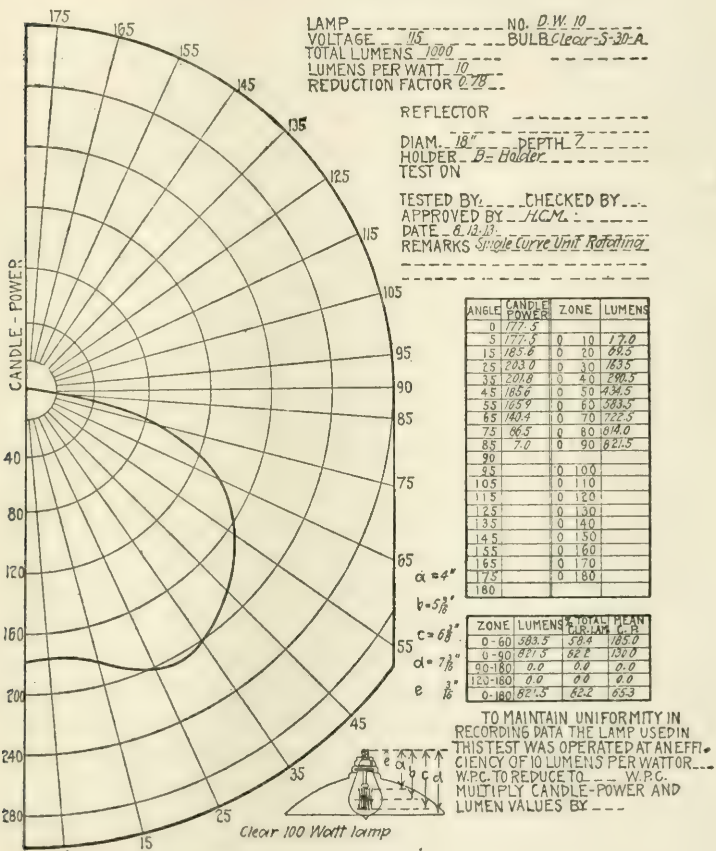


Fig. 13.

purposes of comparison in order to determine the most suitable for a case in question. The fact that these curves have been made

with lamps operated at various efficiencies and with different reduction factors has resulted in considerable confusion and many erroneous conclusions. The practise has been to obtain and put on file a curve for each kind and size of unit, and to revise the entire sheet each time the lamp efficiency changes.

A new method, where the curves are obtained by using a lamp having a known and standard reduction factor and operated at an efficiency of 10 lumens-per-watt, has been devised. A sample curve is shown by Fig. 13. It is intended as a curve which is representative of a type of reflector and which can be applied to various sizes and with lamps of various efficiencies. It will be noted that the values are on a basis of 1,000 total lumens for the lamp, which is very nearly correct for the 100-watt lamp at 1 watt per horizontal candle-power. Assuming the standard reduction factor 78 per cent. for the 100-watt straight-sides lamp, the total lumens at 1 watt-per-candle are 980, or 2 per cent. less than the 1,000 used. On the basis of a reduction factor of 81 per cent., which is standard for the larger round bulb lamps, the total lumens for 1 watt per horizontal candle-power would be 1,018. Therefore, the specific consumption is within 2 per cent. of 1 watt-per-candle for both the straight-sides and round bulb lamps on the basis of 10 lumens per watt, and the average happens to be within 0.1 per cent.

It is seen that all values of lumens are instantly convertible to per cent. of total. The intensity values are as easily converted into per cent. of the horizontal for the bare lamp, with an error not greater than 2 per cent. The original sheet is provided with a blank space for the multiplying factor which must be applied in order to change to a specified efficiency, the intention being to fill in, on blue print copies, the proper factor at the time the sheet is sent out. Where a typical curve is drawn for a type of reflector for all of its sizes, the data for most purposes can be corrected by multiplying by the ratio of the wattage in question to 100 watts. A further correction for efficiency can be made where high accuracy is desired.

For purposes of comparing reflectors no reductions are necessary. The comparisons can be made quickly and without danger of failing to take into account the differences in the lamps used.

It has been found that the number of curves necessary for ordinary illumination work can be cut down to a small part of that formerly used, and, as lamp efficiencies change, it is only necessary to supply a new multiplying factor to bring the curve sheets up to date.

DISCUSSION.

MR. T. H. AMRINE: With reference to the comparisons of the Bunsen and Lummer-Brodhun photometer, I should like to ask Mr. Edwards something about the experience of the operators in this test with the Bunsen photometer as compared with the Lummer-Brodhun, whether they had equal experience on the two photometers. The reason I ask this is that we get on the Bunsen photometer with experienced photometrists somewhat better accuracy than that indicated by an average deviation of 1.5 per cent. For instance, I have the result of tests of 3 different operators on both the round and the star shaped spots from some 20 tests, in which the photometer bar has masked so that the operators could not see what readings they were getting. The average deviation for the 3 operators was 0.497 per cent. These were, of course, experienced photometer operators.

MR. S. L. E. ROSE: The paper just given by Mr. Edwards contains a great deal of valuable information to photometrists. The part of the paper I want to emphasize is that of making distribution curves using a 100-watt lamp operated so as to give 1,000 total lumens. This one curve can then be used for other reflectors of the same type and different size lamps by simply applying a factor. The factor will also take care of the efficiency at which the lamps are to be operated in practise. This will probably not appeal to the layman as usually he does not want to bother multiplying by any factors; but to the engineer it should appeal very strongly.

MR. L. J. LEWINSON: Some of us are probably interested in the commercial aspect of photometry. It might be in order to ask Mr. Edwards about the relative speed attained with the Lummer-Brodhun and Bunsen photometers. Presumably the time reuired to make a measurement is longer with the former. Does the increased accuracy of the Lummer-Brodhun photo-

meter overbalance the extra time required for a measurement, and also the increased eye fatigue which probably results?

While I have no figures which are directly comparable to the results shown in Fig. 1, the following records may be of interest:

At the Electrical Testing Laboratories we use 3 photometers equipped with Bunsen screens for our commercial work. As a regular routine, about 20 per cent. of the lamps measured at each photometer are checked at another photometer. One photometer is considered as the standard, and the variations of the measurements made at the other photometers computed. We have made daily averages of these variations over long periods, and find that during one year the average variation from the mean value was about 1.17 per cent. and for the following year about 1.2 per cent.

DR. H. E. IVES: In connection with this discussion, several years ago a paper came out by Dr. A. E. Kennelly in the TRANSACTIONS, of the National Electric Light Association entitled "Accuracy in Photometry."* I would recommend that those interested in the present paper to look it up. Several of the questions named to-day are answered in it.

MR. M. LUCKIESH: This paper has brought out some particularly interesting points and the measurements have settled some doubts in my mind in a graphical manner. In regard to diffusing screens, the best that I could make or otherwise procure showed errors of about the same magnitude as those examined by the authors. Owing to the failure of the screens to be perfectly mat we might be led to believe that this is always a serious matter. In a room with dark walls the illuminometer measurements will be smaller in value than the computed measurements. However in all practical cases there will be some light reflected to the photometer screen by an indirect route. This will tend to compensate the apparent deficiency. In many interiors this additional light flux which is not computed will amount to an appreciable fraction of the total light flux falling on the working plane. This fault of diffusing screens is therefore not a very serious matter in most cases. The authors have illustrated some simple procedures which might well be

* *Proc.*, National Electric Light Association (1908), p. 208.

adopted by those wishing exact knowledge of the accuracy of their photometric data.

MR. E. J. EDWARDS (In reply): Regarding the question brought up by one speaker, I would say that the inverse square law applies even to very concentrating headlights at distances beyond a certain point up to which there is likely to be crossing of the rays from the unit. Attempts to carry on investigations along the lines of this test with such highly concentrated units as ordinary headlights are very difficult, due to lack of uniformity of the cross section of the beam. It is very hard to place the photometer to catch the same beam at the various distances. Tests, so far as they have been carried on, seem to indicate that the inverse square law holds even in the case of headlights and other projecting units, although the effective distance as obtained by a graph might not show as good agreement with the actual measured distance as in the case of the less concentrating type of units used for general illumination purposes.

Mr. Luckiesh asked as to the effect of the diffused light on the test plate error curves in any assumed system. In the computations shown, equally spaced stations were taken and the illumination computed from a distribution curve and the summation was carried out to a distance away from the unit where the increment of illumination became negligible. This method takes no account of the diffused light from walls and ceiling. I think it would be very hard to determine accurately just how much the error curve would be affected by diffusion, but surely, in the cases shown, 90 per cent. or more of the total light reaching the test plate would, under average conditions, come directly from the units, and therefore, the effect on the curve would have to be very small. Even the diffused light component would have to have somewhat the same error since it reaches the test plate from all angles.

It is gratifying to the authors to note that Mr. Rose emphasized the importance of considering the general adoption of a simplified means of handling distribution curves such as the thousand-lumen method suggested in this paper. In the case of a curve applying specificially to a 250-watt unit, rather than to

a type of reflector, it would probably be better to plot on the basis of 10 lumens-per-watt instead of 1,000 total lumens.

In reply to Mr. Lewinson's question regarding eye fatigue and the time taken to make settings with the Lummer-Brodhun photometer, I would relate briefly our experience in changing over our equipment. When certain operators, who had been accustomed to using the Bunsen screen, were asked to use the Lummer-Brodhun, they complained very much because of the fatigue which seemed to result from using one eye instead of two, and also because it seemed to take longer for settings. It was only by promising these operators that they would not have to use the Lummer-Brodhun unless they preferred them at the end of a trial period that we were able to get them to willingly try them out. At the end of a week they said they were able to make the settings more easily and more quickly, although they used but one eye. The narrower range of doubt in the settings seemed to give the operators a greatly increased confidence in their work.

In this connection I might also answer Mr. Amrine's question regarding the experience of operators. The results as shown in Fig. 1 were for an operator about equally experienced with both photometers. There were other results obtained in this test by operators who had been accustomed to using only the Bunsen screen, but since a fair comparison of inherent accuracy of the two systems was desired rather than the accuracy as applied to any certain class of operator, they are not included in Fig. 1. It was found that the operators who were unaccustomed to the Lummer-Brodhun read with nearly as low an average deviation as the experienced operator, but were incorrect in actual value because they set according to some appearance of the field other than that resulting from equal intensity on both sides. I agree with Mr. Amrine that it is possible for an experienced Bunsen operator to obtain average deviations as low as ½ per cent. as noted by him. But on the same basis we believe a very expert operator under most favorable conditions might show less than 0.2 per cent. with the Lummer-Brodhun.

The flicker photometer was not considered at all, since it had never been the subject of thorough investigation by us. The

paper is not intended as a comprehensive one on the subject of photometry.

Another speaker has shown a test plate error curve plotted on the same basis as our Fig. 6. It is interesting to note that his tests show a smaller error. Our test included some plates of the same make as those he mentioned, and, although they showed a somewhat less error than the average, they came out greater than the result he showed. All of the plates tested showed the same characteristic shape of error curve. We did not find that the error reached a maximum at a certain intermediate angle. It seemed to increase in a smooth curve out to the limiting angle where the error value becomes indeterminate. Even with plates as good as he used it is evident that test plate error is important, and accounts for many discrepancies noted in the past.

THE STATUS OF THE LIGHTING ART.*

In every branch of human endeavor there comes a time when it is advisable to appraise progress. The periodic test of students' knowledge, the counting of cash in the till, the taking of stock in a mercantile establishment, the mariner's observation, reconnaissance in military manoeuvres,—are all recognitions of the need for measuring progress and determining status. In all forward movements such determinations are admittedly indispensable.

The science and art of illumination have made considerable progress in the recent past. The growth and improvement have been rapid and of a nature to command widespread attention from scientific, commercial and humanitarian viewpoints. Ramifications are so numerous, however, and the variation in practise is so great that, even in the opinions of those best qualified to judge, it is difficult to fix the present status.

To possess a thorough knowledge of the status of the lighting art would be of great advantage. First, it would constitute a record for future reference and for comparison with corresponding records which may be compiled in later years, and, second, it would indicate points of greatest weakness in knowledge and practise, and make apparent the directions in which, because of such weakness, this Society has the greatest opportunity for useful service in the near future.

Because of conviction that a very useful purpose would be served by a record of knowledge of the principles of illumination already attained, and by a review of existing practise in the art of illumination, it has been thought advisable to undertake the compilation of facts in an endeavor to record the status of the lighting art in the United States of America in the year 1913. The obstacles in the way of success in such an effort are, however, considerable. The range of variation in practise is so large as to make it impracticable to present a really comprehensive survey. More numerous agencies than are available are required in order to obtain sufficiently reliable and consistent

* Presidential address by Preston S. Millar at seventh annual convention of Illuminating Engineering Society, Pittsburgh, Pa., September 22-26, 1913.

records of practise in various parts of the country and in the several branches of illumination. To present a fittingly authoritative review, a more accurate and detailed knowledge than the writer possesses is essential. These obvious obstacles, however, were deterrents of too mild a nature to dissuade from an attempt regarded as desirable.

With a view to securing information regarding lighting practise, questions were prepared and issued about the first of July to representative individuals and commercial organizations of the following classes:

- Central stations (300 lists).
- Gas Companies (300 lists).
- Municipal engineers (200 lists).
- Ophthalmologists (200 lists).
- School associations and commissions (200 lists).
- Street railroad companies (200 lists).
- Manufacturers of incandescent lamps (in various quantities).
- Manufacturers of mantle burner lamps (in various quantities).
- Manufacturers of arc lamps (in various quantities).
- Manufacturers of acetylene supplies, tips, etc. (in various quantities).
- Manufacturers of oil lamps (in various quantities).
- Manufacturers of small isolated lighting plant equipments (in various quantities).
- Manufacturers of gasoline, acetylene, etc. (in various quantities).
- Manufacturers of lighting glassware (in various quantities).
- Fixture manufacturers (in various quantities).
- Arc lamp post manufacturers (in various quantities).
- Railroads (in various quantities).
- Street lighting companies (in various quantities).

The country was divided into areas of approximately 1,000,000 population each, and so far as practicable, lists of questions were sent to possible sources of information in each section of 1,000,000 population. In all there were 128 questions, many being

duplicates of questions which appeared on other sheets. Approximately 1,750 lists of questions were issued. The questions as a whole dealt with the recognized fundamentals of illuminating practise, though in all cases the attempt was made to adapt them to the knowledge which the correspondent was understood to possess.

It was anticipated that the replies to these questions would be relatively few in number and that the information thus furnished would be inadequate, both in respect to reliability and comprehensiveness. It was felt, however, that in the aggregate the information elicited would be interesting and valuable. Furthermore, the submission of these questions would be of some value in attracting attention to the need for improvement in lighting practise, and in drawing attention to this Society as the exponent of good illumination.

Approximately 20 per cent. of those receiving the questions promised to supply such information as they possessed or could obtain, and approximately one-half of these have been heard from.

In discussing the subject, it is necessary to adopt some form of classification, if each department of knowledge and practise is to be considered intelligently. It is possible, and it is perhaps customary, to classify with respect to the nature of the installation and of the premises illuminated. It has seemed preferable in this case to classify according to those features which determine the success or the failure of the illumination, irrespective of the nature of the installation. Light should be of proper quality and the lighting equipment should be installed suitably. In the present stage of our knowledge it is considered that illumination is satisfactory if it is correct in regard to certain qualities of light and to certain features of utilization. These it is presumed to present to you as—

THE CATEGORIES OF ILLUMINATION.

Light	Utilization
Intensity	Contrast
Direction	Congruity
Diffusion	Hygiene and Safety
Color	Cost
Steadiness	

The categories are believed to be inclusive of all ordinary features of illumination which should receive attention from the illuminating engineer. They are not independent of one another, but are interconnected in such a way as to make it impracticable to discuss any one without referring to one or more of the others. It is also impracticable to arrange them in order of importance, since their relative importance varies with local conditions and with the requirements of the installation.

In the following discussions of the various qualities of light, features of lighting practise and correlated matters, the information made available through the lighting survey which has been described has been combined with such material as could be obtained from other available sources, and the whole is compressed into a brief review.

INTENSITY OF LIGHT.

Intensity is a quality of illumination which has received very general attention from the earliest days of illuminating engineering. Its great importance was recognized early, and led to study and to the development of photometers for facilitating such study. Early writings on illumination rarely failed to include a table setting forth views as to the intensities which ought to prevail in various classes of installations. It is true that these statements were very largely restricted to the mean horizontal illumination at some height, usually 30 inches, above the floor, and neglected other important aspects such as wall brightness. Yet emphasis upon intensity undoubtedly prompted increase of light in installations where it had been inadequate, and tended to raise the standard everywhere.

In many classes of lighting the intensity standard has been increased greatly within the last few years. Street lighting, very generally inadequate, has felt this advance. The use of more powerful illuminants, the growing appreciation of importance of lighting business streets well, and the influence of merchants' display lighting systems have operated to increase the standard of illumination intensity. In the middle and better class stores a high intensity of illumination has been found to have a merchandising value, and the intensity standard has been largely increased in the past few years. In large intelligently conducted industrial

plants the influence of improved lighting upon output and upon safety of employees is evidenced in increased light intensity. In small factories, as in small stores, this improvement is less marked. Sign lighting in the past few years has increased greatly, indirectly promoting intensity increase particularly in street lighting. In residences the advance has been felt perhaps less than elsewhere.

The attitude of manufacturers of illuminants and of lighting companies is an important element in determining the trend of practise in regard to intensities. Manufacturers of gas mantle lamps have been active in promoting the use of their product, displacing open flame burners with large increases in intensity. It would appear that there exists to-day an opportunity for gas companies to contribute largely to the improvement of illumination by more actively promoting the substitution of mantle lamps wherever open flame burners are still in use.

In the electric lamp field the manufacturers have exploited the Mazda lamp widely and their efforts have been seconded more or less by central station companies. In some cities the central station company has pushed the use of the Mazda lamp actively with very beneficial results. In other cities the central station company has not taken an active part in making this improvement in electric lighting available to its customers. An indication of the extent to which the Mazda lamp is now employed will be found in the sales records of the electric lamp manufacturers, which show that for the 3 months May, June and July, 1913, the sales of the several types of lamps have been as follows:

	Per cent.
Gem and Carbon	37
Mazda	63

When it is remembered that each Mazda lamp lasts two or three times as long as a carbon or Gem lamp, it will be seen that the use of Mazda lamps has now become very general, especially when it is recognized that in general it is the more extensively used lamps which are of the Mazda type.

The sales records of lamp manufacturers furnish another interesting evidence bearing upon the increase in the light intensity standard. This is the average candle-power of the lamps sold during recent years.* These records are as follows:

* Courtesy of General Electric Co.

Year	Approximate average candle-power of all incandescent lamps sold
1906	18
1907	19
1908	21
1909	23
1910	25
1911	26
1912	29
1913 (estimated)	32

Standard practise in regard to light intensity depends upon conditions other than simple illumination requirements. The standards vary in installations of similar class in different cities. For example, in some cities merchants have not come to appreciate the advantage of adequate, well designed illumination to the extent that they have in other cities. Again in some cities the installation of "white way lighting" has been found to militate against successful show window lighting, the street light of higher intensity being considered sufficient to illuminate the show windows for ordinary purposes. In other cities similar installations have operated to increase the intensities employed in show window lighting, it being found that in contrast to the lighting of the street, more light is necessary in order to make the window displays as prominent as they were when the street lighting was inadequate.

In few classes of installations is it practicable to measure the advance in light intensity throughout a period of years. While representative data are available for modern installations, very generally they are lacking for the older installations. In railway car lighting there is an opportunity to measure the progress which has been made, due to the fact that the older cars, which have antiquated lighting systems, are continued in service on branch lines long after their type has become obsolete. Minick* has availed himself of this opportunity to place upon record the average illumination intensities which are typical of the several systems of lighting which have been used in the lighting of day coaches. This record is as follows:

* I. E. S. Transactions, May, 1913, page 214 and communication to the writer.

DAY COACH LIGHTING.

Installed during	Description of illuminants	Average horizontal foot-candles 36 inches above floor
1850 to 1875	Oil lamps—2 wicks feeding one flame	0.5
	—annular wick	1.0
1875 to 1900	Pintsch gas —4 fish-tail flames	1.5
	—4 mantle cluster	1.65
1880 to 1900	Carbureted gasoline —center draft	1.3
1900 to date	Electric —50-watt opal dip lamps and flat reflectors	1.4
	—50-watt clear lamps and satin finish bowl reflectors	3.0

Typical illumination intensities for artificial lighting of certain classes are indicated in the following table:

TYPICAL INTENSITIES OF ARTIFICIAL ILLUMINATION.

Class	As measured through	Foot-candles Average	Usual range
Street lighting—			
Principal streets in cities	Horizontal plane of street surface	0.4	0.25– 2.0
Important side streets	Horizontal plane of street surface	0.15	0.1 – 0.25
Residence streets	Horizontal plane of street surface	0.04	0.01– 0.10
Store lighting	Horizontal plane 30 inches above floor	4.0	2.0 – 6.0
Show window lighting	Plan of trim	18.0	12.0–25.0
Factory lighting	Horizontal plane 30 inches above floor	3.0	2.0 – 6.0
Office lighting	Horizontal plane 30 inches above floor	3.0	2.0 – 4.0
Residence lighting	Horizontal plane 30 inches above floor	1.5	1.0 – 3.0
Railway car lighting	Horizontal plane 30 inches above floor	2.0	1.0 – 3.0

The trend in illumination intensities is upward. Higher efficiency lamps are being developed, particularly in large illuminants suitable for lighting streets, public squares and large rooms such as factories, armories, etc. With the increase in efficiency there is coming into our practise a greater insistence upon good candle-power maintenance, both that inherent in the illuminants and that secured through careful maintenance of the lighting equipment. Daylight illumination in interiors is perhaps five to ten times as intense as that provided by our usual artificial light-

ing. As the artificial lighting is improved, attaining greater merit in respect to diffusion, the tendency appears to be to increase the intensities. Latest experiments seem to indicate that it is not improbable that when we shall have attained more complete knowledge of the principles of good illumination, we shall find that the intensities now available in the illumination of interiors by daylight will have to be approached by artificial light in order to satisfy the requirements. It is apparent further that as appreciation of the beautifying opportunities in illuminating engineering grows, esthetic considerations impose requirements for greater light production. Thus the requirements of ocular hygiene and of esthetics combine in demanding the production of more light than was formerly required in order to provide acceptable illumination. The growing appreciation of the importance of good lighting is raising the standard, making a still further general demand for the production of more light.

DIRECTION OF LIGHT.

Direction of light has not received the same extended consideration as have some other features of the illumination problem. It is forced upon attention, however, in certain classes of work where improper direction brings annoying shadow or glare. In such cases the remedy is sometimes found by changing the direction of the light.

In general, artificial lighting is provided from ceiling fixtures in the center of rooms or bays, though often wall brackets are used alone or to supplement center lighting. This involves a downward direction of the utilized light. Where the ceiling is employed as a secondary source, as in indirect lighting, engineering thought seems to favor designs which will very largely preserve a downward direction for the light. Daylight illumination of interiors, on the other hand, is very generally from side windows, and the lighting has a strong component which is almost horizontal, though the direction is usually slightly downward.

One of the earliest evidences of appreciation of the importance of proper direction in lighting is the well established tradition that in reading "the light should come from over the left shoulder." Many of the tenets of illuminating engineering, though unrecognized in the formulation of this precept, are evi-

dent as the underlying cause which has led to its wide dissemination and general acceptance. It was the outgrowth of reading experience in a time when a limited amount of reading was done with the aid of a single illuminant in a room. This homely saying correctly indicates conditions for reading which avoid shadow and glare and best contribute to the ocular welfare and comfort of the reader. Under the conditions of use which obtained when one or more members of a family read by the aid of light from an oil lamp, the portability of the light source, and the freedom of the reader to choose any desired position, made compliance with the precept entirely practicable.

Modern conditions, involving immobile light sources and fixed positions for a number of workers in the same room, complicate the problem severely, and demand much more adroitness for its successful solution. Indeed were proper direction of light the only possible solution, as is implied by the ancient precept just quoted, the problem in many cases would be very difficult.

Recently, question has been raised as to the general propriety of downward light.* Arguments have been advanced in favor of a direction of light which is from the side. It is quite possible that in the near future developments in illuminating practise may result in less general adherence to a downward direction for light than characterizes present practise.

Meanwhile, however, the general downward direction of light is very common. In store and office lighting, reflectors designed to redirect the light downward are employed very generally. Only 15 to 25 per cent. of stores and offices employ illuminants without auxiliaries of some kind. In many of these exceptional installations the lamps are placed so near the ceilings that a general downward direction of light is obtained in spite of the absence of redirecting auxiliaries. Of the 80 per cent. installations which employ lighting auxiliaries, probably four-fifths, or about 65 per cent. of all installations employ some device designed to direct much of the light where it is considered to be most useful.

Under daylight conditions the direction of light is likely to be from the side, and altogether too little attention is paid to adapt-

* Ives—Some Home Experiments in Illumination—I. E. S. Transactions, June, 1913, Page 229.

ing conditions in order to secure the best illuminating results. Indeed where a number of persons are at work in a large room illuminated from the side by daylight, it is well-nigh impossible to dispose things so that there shall be practical freedom from shadows and glare.

Direction of light is so intimately associated with diffusion in contributing to the merit of an installation, that its further consideration may well be included under the following caption.

DIFFUSION OF LIGHT.

Diffusion of light in earlier discussions of illumination problems was often regarded simply as a quality secured as a result of an effort to conceal light sources and reduce their intrinsic brilliancy. Its influence upon the appearance of a room and of objects in a room was recognized, and its importance from the ocular standpoint was often considered, though not fully appreciated. Importance as an element contributing to the reduction of sharp shadows completed the list of recognized effects of diffusion. Larger experience in illuminating practise and more recent experiments and research have brought about an increased and more widespread appreciation of the importance of diffusion as one means of diminishing glare from reflecting surfaces and promoting ocular welfare in general. Increased appreciation of the importance of securing a proper degree of diffusion is perhaps the most notable development in the knowledge of illuminating engineering during the past two or three years. A few years ago the cry was for the use of efficient reflectors which directed the light downward, increasing the horizontal illumination intensity for a given light production, or decreasing the amount of light which would have to be produced in order to provide a given illumination intensity.

At this time such reflecting devices, while regarded as useful, are recognized as inadequate unless some means of providing a fair measure of diffusion is employed. Thus the use of mat reflecting surfaces is growing. One year ago, it was found that among 52 types of simple glass and metal reflectors purchased upon the open market 38 had been provided with etched or other diffusing surfaces.

Where diffusion is lacking, multiplicity of sources is of some assistance, since in some cases glare may be overcome by increased intensities of light from other directions. Multiplicity of sources, however, means multiplicity of shadows.

Extremes of diffusion are rarely required. Too much diffusion means characterless illumination and may mean eye-fatigue. Too little diffusion involves glare. The degree of diffusion which characterized even the better lighting installations of a few years ago is now recognized as inadequate. "Semi-indirect" and "indirect" lighting succeed in many installations because of the higher degree of diffusion which their use involves.

Diffusion of light cannot be separated from intensity of light in discussions of this character. Obviously, light cannot be diffused without loss. Some have felt that with diffused light a lesser intensity is satisfactory. Tests have been reported which purport to establish this point. It is very doubtful, however, if such is the case. With a correct degree of diffusion it is entirely practicable to determine what intensity of light is most satisfactory for a given purpose. With improperly diffused light it has been found that the same intensity of light is unsatisfactory. This has been taken to indicate that proper diffusion of light results in a decreased intensity requirement. When the diffusion is inadequate, the lighting cannot be satisfactory with any intensity provided by the same source or sources. When subjects who are being experimented upon are told to increase the intensity until the illumination is satisfactory in order to compensate for the lack of diffusion, it is not unnatural that the result should be a report that increased intensity compensates for the lack of diffusion, giving rise to the conclusion that increased diffusion permits decreased intensity. It is submitted that such an effect has not been demonstrated and there is no reason to suppose that insufficiency of diffusion can be compensated for in any other way than by increasing the diffusion. Hence the intensity requirement with properly diffused light cannot be said to be less than it is with improperly diffused light. Each increase in light diffusion has brought with it the necessity for increasing the light production in order to compensate for the loss in efficiency involved in the diffusion.

In one-half to two-thirds of the total installations upon which reports have been obtained, certain degrees of diffusion have been obtained, either through the employment of diffusing globes, by depolishing inner surfaces of reflectors, or by means of indirect lighting.

COLOR OF LIGHT.

The modification of light to produce desired colors has been very generally employed in recent years for decorative purposes. This usage has been very largely the outgrowth of effort intended to secure decorative results. The ends to be achieved have been more or less clearly defined, but the means to be employed have in general received too little attention. Color in lighting has been the agent of the artist rather than of the physicist or engineer. In its employment empiric rather than scientific methods have been followed. A quality of light which must ever commend itself to the artist and which can be employed effectively only through artistic appreciation, color remains both a physical and a physiological phenomenon which must be applied scientifically to secure thoroughly effective results.

The art of illumination seems to be upon the verge of a marked advance due to appreciation of the possibilities of color manipulation in lighting. Illuminants are available ranging in color from the neon tube through the Moore tube and the metallic electrode arc to the mecury-vapor lamp among luminescent light sources. The incandescent light sources offer a narrower, though material, range of color values. The employment of these variously colored illuminants in conjunction to produce color effects is inherently costly and troublesome, and likely to be practised only in special cases, as in the notable installation in the Allegheny County Soldiers' Memorial Hall, Pittsburgh.*

The modification of the light of many or all of these illuminants to secure light of desired quality is a field which, now largely uncultivated, offers opportunities of which the illuminating engineer is beginning to avail himself.

The use of differently colored illuminants for commercial purposes is beginning to be appreciated. In a few dry goods stores,

* I. E. S. Transactions, Vol. VI, 1911, Bassett Jones, Jr.

small area lighting by illuminants which simulate daylight has been provided.*

For many purposes we aspire toward light of the color of daylight. The earliest successful illuminant for this purpose, namely the Moore carbon dioxid tube, produced light of practically the desired quality. Later efforts in the modification of light of electric incandescent lamps, incandescent gas mantle lamps and intensified carbon arc lamps, have attained some measure of success. It is understood that all these forms of artificial daylight have come into use to a limited extent, though the low efficiency of all is a deterrent preventing their application upon a large scale.

We appear to be upon the verge of developments in arc lamps which are likely to result in relatively high efficiency illuminants of color values so near to daylight that it would not be surprising if the slighter modification of light which would be entailed in order to produce artificial daylight would be accomplished with a loss which would not reduce the efficiency of the lamps below the practicable limit, and which, therefore, might result in artificial daylight illumination upon larger scales. Such a consummation is to be desired, because artificial daylight will not only be useful in a practical way, but experience in its utilization is likely to extend the realm of our practical knowledge of illuminating principles.

Meanwhile it is becoming increasingly apparent that for certain purposes, as the lighting of residences, ballrooms, etc., white light is not acceptable under existing conditions. Having become accustomed for generations to the employment of light in which the long wave-lengths are more accentuated, we have either adapted ourselves to that condition, or there is some quality inherent in its present application which makes it more satisfactory for social purposes than white light. The amber mantle as a substitute for the ordinary mantle employed in gas lighting caters to this peculiarity and renders the gas mantle lamp far more acceptable for certain purposes. Among electric incandescent lamps there is reason to believe that the light of the tungsten filament lamp might be modified to advantage in order to produce a

* For example see Shalling—Store Lighting, I. E. S. Transactions, January, 1913.

more acceptable color for social lighting. Attention is being given to these matters, and it is reasonable to state that the art is upon the verge of developments which within the next few years will extend employment of color in lighting, and that lighting auxiliaries will be developed along scientific lines which will yield a wide variety of tints with a minimum practicable loss in efficiency.

The physiologist, and the psychologist, as well as the artist, are interested in the color of light. Our knowledge of these matters is not great, and its possession is not general. While it appears probable that we are upon the threshold of a general effort to develop the use of color in illumination along scientific lines, thereby upholding and encouraging artistic endeavors in this direction, it remains true that more encouragement should be offered to the study of the effect of light of different colors upon the eye and upon the mentality. Only as artist, psychologist, physiologist and engineer combine, will the employment of color in illumination be developed to a point of maximum effectiveness. The most encouraging fact in this connection is the activity of this Society in promoting the co-operative study of this problem and in disseminating knowledge accumulated through such study.

STEADINESS OF LIGHT.

Steadiness of light is so important a fundamental that most modern illuminants employed in indoor lighting are free from serious objection on this score. Outdoors the requirement for steadiness is less rigorous, and illuminants producing light which is relatively unsteady find employment more readily. Among such are, in varying degree, arc lamps and the flame illuminants, including open flame gas lamps, and some types of gas mantle lamps. The flame illuminants are inclined to be unstable when exposed to wind. In modern types of gas lamps this difficulty is reduced. Among arc lamps, the flaming arc is particularly unsteady. Improvement in the steadiness in the light from all arc lamps is effected when the current density at the electrodes is increased. The tendency to operate these lamps at higher currents, as noted elsewhere, brings greater stability in addition to higher efficiency.

Cyclic fluctuations in electric lamps constitute another form of unsteadiness of light. This effect is the more notice-

able in the case of arc lamps. Under some conditions it has been found practicable to operate incandescent lamps upon 25-cycle alternating current circuits. This frequency is about the lower limit and under some conditions the flicker of lamps so employed is objectionable. Arc lamp operation upon 25-cycle current is impracticable where good lighting is the desideratum.

In general, steadiness of light is so obvious a fundamental that a degree of unsteadiness which becomes obtrusive is rarely tolerated.

CONTRAST IN ILLUMINATION.

Contrast, here regarded in a comprehensive sense, is a most important factor in the utilization of light.

Exposed light sources within the field of vision, occasioning too great contrast with the surroundings to which the eye is adapted, are detrimental to vision. One of the earliest canons of illuminating engineering branded exposed light sources as the cause of ocular discomfort and, under extreme conditions, of impairment of vision. The development of more powerful and brilliant light sources has emphasized the importance of this principle. Reduction in the specific intensity of light sources was recognized as a means of mitigation. Tables of specific intensity of various light sources were prominently featured in the earliest discussions of illuminating engineering. The low specific intensity, for example, of the Moore tube was urged as one of its chief merits. But that exposure of light sources was not generally recognized as a serious menace to eyesight and a source of discomfort, is attested by the designs of lighting fixtures and glassware of the period. Catalogues of lighting equipment furnished by the leading manufacturers at that time show designs which in the light of our present practise appear almost barbarous in their defiance of this first principle of illuminating engineering.

The evil effects of exposed light sources include, as previously mentioned, ocular discomfort and, under certain conditions, impairment of vision in the sense both of injury to eyesight and diminished visual power. These effects in rather loose terminology have been attributed to glare. A number of causes and effects differing materially in character have been classed as glare without proper distinction, due to their nature. The study

of glare and its evil effects, insofar as these are concerned with the exposure of light sources, received a notable impetus in the early years of this Society's history. This was particularly true of glare as an agent which diminishes visual power.* Following upon the discussion of glare in the sense here considered, there came a more general appreciation of the advantages of concealing light sources. Leading manufacturers of lighting appliances discontinued some of the most prominent offending designs and the newer designs evidenced more attention to this important aspect of the problem. While on all sides one finds evidence of continued neglect of this important fundamental, yet we may feel that, at least by lighting practitioners, there is a thorough understanding of the serious nature of exposure of light sources, and that a real effort is being made to eliminate it from our practise. It is now generally recognized that entire concealment of the light source as in indirect lighting, reduction of its brilliancy by the aid of diffusing media, as in much of the direct and "semi-indirect" lighting, or the removal of the light source from the ordinary field of view, is an essential to good lighting. Very generally these principles are being put into practise. Flat reflectors, which exposed the light source, are being replaced by bowl reflectors which conceal it from ordinary view; manufacturers of gas lamps report growing use of diffusing rather than clear globes; manufacturers of electric lamps report increasing use of frosted lamps; the use of indirect and "semi-indirect" lighting fixtures is growing rapidly; new installations of street lamps for civic lighting are very generally mounted higher than was the practise a few years ago; the proportion of bare lamp installations is decreasing.

Exposed light sources of the more usual types are more brilliant than is the sky, and surroundings are apt to be less bright under artificial light than they are in the daytime. Thus greater contrasts prevail in artificial lighting. In the better lighted installations, however, improvement is now being effected both through the reduction of the specific intensity of the sources and through the increase in the brightness of the surroundings.

Glare from reflecting surfaces due to specular reflection is occupying much thought of investigators and practitioners at the

* A. J. Sweet, Journal Franklin Institute, May, 1910.

present time. This again involves the question of contrast. Indeed, all manifestations of glare are but little more than improper contrast. A printed page of glossy paper may give rise to a serious condition of glare due to specular reflection. This means that one views the imperfectly reflected image of a light source which, in contrast with the surroundings, is of excessive brightness. The result is ocular discomfort. If glossy ink has been used in printing, it may be difficult or even impossible to discern the imprint. This is a case in which the excessive specular reflection which causes discomfort by too great contrast with the surroundings is complicated by too little local contrast to permit of reading the glossy black letters, which reflect specularly almost as well as the surrounding surface of the paper.

This element of contrast is receiving a fair share of the attention which it merits, and our knowledge of the principles involved is growing rapidly. This is followed by improvement in the design of new installations in which such knowledge is applied. In general, therefore, it may be said that improper contrast which manifests itself as glare either due to exposed light sources or to reflections from specular surfaces is rapidly being brought under control in the installations which are receiving illuminating engineering attention. The lesser degrees of difficulties involved in improper contrast are, however, not so thoroughly understood or appreciated; our knowledge appears to be in need of considerable extension and our practise appears to suffer from lack of proper care for this important feature of the utilization of light.

CONGRUITY.

The past 2 or 3 years have witnessed a marked increase in general appreciation of the importance of the esthetics of illumination. It is becoming generally recognized by lighting practitioners that lighting equipment as well as the illumination produced must be in harmony with the character of the premises which are illuminated.

In the early development of the science and art of illumination it was but natural that the physical and engineering aspects should receive first attention, for these underlie the entire art. It was

but natural that first developments should evidence incongruities. This period of illuminating engineering is now being outgrown. The art is now approaching the period of adolescence in which the acquirement of knowledge is rapid and preparation for mature effort is the keynote. At this time it is being appreciated that congruity in the utilization of light in any installation is a desideratum of first importance. It is just as inartistic to locate highly embellished ornate and inefficient fixtures and glassware in a machine shop, as to hang tin shades in an elegantly furnished drawing room. Error, however, occurs commonly in the use of inartistic lighting equipment where artistic design is required, and it is in this aspect of general practise that one of the great needs for improvement is apparent.

It is recognized that the illuminating engineer should be conversant with and appreciative of art in its several phases if his work is to reveal in an intelligent sympathetic manner the best of the design. Some instances are encountered where only the artist can do justice to the requirements. In such cases the illuminating engineer should be guided by the artist, and he should be able to accomplish the desired end more effectively and with a lower cost than the artist can. The latter fully appreciates what he desires, but presumably has not familiarized himself with lighting technique to the extent which enables him to accomplish his purpose so well as can the illuminating engineer. It is believed that the events of the past 2 or 3 years have contributed toward a somewhat better mutual understanding and that in the very near future we shall enjoy a fuller measure of the needed hearty co-operation of architects, decorators and fixture designers, thereby achieving improvements in the artistic phases of illumination which are so much needed at the present time.

In this connection it may be noted that a most important factor in the betterment of illumination conditions, artistically, is improvement in the design of stock fixtures and stock lighting auxiliaries. Any given type of fixture must of course be designed for one set of conditions and cannot be expected to be congruous in a wide variety of installations. It may, however, be made tasteful in itself, free from objectionable features and well adapted for general use under average conditions of the class for which it is designed. When considering the artistic aspects of

illumination, it is not well to restrict thought to individual designs which of course are expected to surpass stock fixtures being at once more pleasing and congruous when applied in the installations for which they are designed. It should be remembered that a 5 per cent. improvement in stock fixtures affecting large numbers of people may be of much greater value than a 100 per cent. improvement in a distinctively designed installation.

Residences and certain other classes of installations may be said to be equipped very generally with fixtures which cannot be approved either from the artistic, hygienic or efficiency standpoints. This is particularly true of installations which date back 5 years or more. It is especially true of combination fixtures designed to permit the use of either electric or gas illuminants. The presence of these fixtures which are neither tasteful in themselves nor consistent with the standard of good taste exhibited in the furnishing of rooms in the middle and better class residences, constitutes a barrier to the improvement of lighting conditions in residences. The first step toward a general improvement in such lighting conditions would appear to be the wholesale replacement of such fixtures. Such is the crying need of the time. The way of accomplishing this is not clearly indicated. The extension of lighting improvements to residence and to some other classes of lighting is dependent upon the displacement of such fixtures.

It is fortunate that displacement of incongruous lighting equipment by equipment which would be suitable from the artistic or efficiency standpoint would bring about automatically an improvement in installations from the standpoint of ocular welfare. If the requirements for artistic and hygienic equipment were diverse or incompatible, the situation would indeed be difficult. As it is, the happy concordance of hygienic and artistic requirements constitutes a demand for betterment which cannot be ignored.

HYGIENE AND SAFETY.

In ordinary lighting practise the qualities of illuminants are such that laws of hygiene are rarely transgressed. Much has been written regarding unsanitary effects of various illuminants, but usually it has been found that such articles are the work of the press agent of some manufacturer or promoter of rival il-

luminants. Ordinarily, ventilation is sufficiently good to avoid deleterious effects from noxious gases. Most artificial illuminants are not sufficiently strong in ultra-violet light to be injurious. The quartz mercury-vapor lamp perhaps forms an exception, but the heavy glass globe which is invariably used with it when employed for lighting purposes is sufficient protection.

On the other hand, the use of light promotes sanitation in securing greater cleanliness wherever it is applied. Likewise the more liberal and judicious use of light promotes safety. This is being recognized in the industries among the larger and more progressive corporations, and more special attention is being devoted to promoting safety by the use of light.

Of much greater importance than general hygiene is ocular hygiene in its relation to illumination. It is not from some deleterious quality of the light of a particular kind of illuminant that harm to the eyes results, but rather from the misuse of light, irrespective of the illuminant. The efforts which are now being made to promote the correct use of light, particularly in the home and in schools, are of incalculable advantage to the public in safeguarding especially the eyes of children during the period of immaturity when they are more susceptible to the ill-effects of misuse of light.

Ocular hygiene is being investigated in a number of laboratories. Generally, conditions of visibility are judged by means of a determination of the threshold visibility value. This involves the determination of either minimum light intensity for visibility, minimum size of object viewed, minimum contrast which can be perceived, or of the time element in the perception of objects at the threshold value. While it perhaps remains to be determined how far the results of such investigations may be considered applicable to practical lighting conditions, yet it is undoubtedly a fact that the information which is being made available as the result of such investigations is advancing the science of ocular hygiene and contributing largely to knowledge of the principles of good lighting. For the further promotion of ocular welfare there is need of further research in which the combined efforts of illuminating engineers, ophthalmologists and psychologists should govern the nature of the investigation. Also there is need

of the application of the results of such investigation to practical lighting conditions. Conditions appear to be such as to warrant the assumption that the next few years will witness considerable advances along both these lines.

COSTS.

It is usually considered that the cost of artificial lighting includes—

Cost of lighting equipment.

Cost of maintaining equipment including interest, depreciation, etc.

Cost of fuel or energy required for operating the system.

Cost accounting in illumination work is well handled in larger organizations and possible efficiency improvements are therefore considered intelligently. Much lighting, however, is not organized and the expense is borne by those who do not handle accounts intelligently and who are not in a position to judge of the ultimate efficiency which may be obtained in lighting by the employment of the several available systems. Thus the use of open flame gas burners and of carbon and Gem lamps continues in many installations where the more efficient mantle burners and Mazda lamps should be used.

Artificial lighting is very inefficient, due first, to the low efficiency of energy transforming devices, and second, to the low light production efficiency of illuminants. To this in many cases must be added unintelligent utilization of light. In spite of its low efficiency, however, the cost of artificial lighting is small. The following lighting costs are suggestive in this connection:

Class of lighting installation	Approximate cost of artificial lighting in proportion to total operating costs
Small wage earner's home—ratio of cost of lighting to total income	1 per cent.
Well conducted large manufacturing establishments which are well lighted with modern illuminants—ratio of cost of artificial lighting to total cost of output exclusive of selling expenses..........	1/3 to 1/2 of 1 per cent.
Large retail mercantile establishments—ratio of total lighting cost to total sales	Probably less than 1.0 per cent.
Small stores—ratio of total lighting cost to total sales	2 per cent.
Modern loft buildings..................	1 to 2 per cent.

Street lighting appropriations by municipalities are of the order of 60 cents to $1.00 per inhabitant per year.

In comparison with the benefits conferred by artificial lighting both in the way of added commercial advantage and extended opportunities in education, social life and recreation, the cost of artificial lighting is remarkably low. In many cases where its beautifying influence is of paramount importance, the cost is immaterial.

In this country there is a strong sentiment in favor of corporate work in the promotion of employees' welfare. The tendency of the American business man toward organization and scientific management was never stronger than at the present time. From both viewpoints, artificial lighting is an important factor and in both respects its cost is small as compared with the advantages derived.

The cost of artificial lighting has been rapidly reduced as a result of the development of improved illuminants and of the greater economies which have been effected in manufacture and operation. Doubtless it will be still further reduced in the near future. This reduction in cost has been largely automatic and the outgrowth of economic conditions.

With the reduction in the cost of lighting has come betterment in lighting conditions. Much that is advanced in the lighting practise in this country is due to the progressive enterprising manner in which manufacturers of illuminants and lighting companies have conducted their businesses. In the future we must look to such organizations to bring about improvements in lighting practise which are needed if the work of this Society is to be applied for public benefit.

Only to an extent so small that it is negligible has the decrease in the cost of lighting been effected through legislation. Recently, however, in a few cities recourse has been had to rate legislation affecting public service corporations in consequence of which relatively low rates have been imposed. These low rates imposed by city regulation, actuated often by political rather than by economic motives, constitute a menace to the success of this Society's work insofar as it may affect the general public. Only as corporations engaged in supplying lighting service earn a

fair return upon their investments can they be expected to continue operation along broadly progressive lines. Only as such policies shall prevail among manufacturers of lighting appliances and in the management of lighting companies, may we hope for rapid progress in the further improvement of lighting conditions. Commercial organizations have great potentialities for good, and we can rely upon a continuance of their assistance only if the further reductions in the cost of lighting are effected in accordance with the development of the economic situation rather than in accordance with the artificial conditions of political regulation.

The foregoing brief review is based in part upon information which has been made available by replies to the questions which were issued as a part of the lighting survey. These replies are extensive and numerous, affording in the aggregate a large amount of statistical information. They apply, however, to so small a percentage of the total lighting industry as to make it seem unwise to present a complete summary of the facts which they make available. All the information which has been obtained in this way is available to the society and may be very useful in the furtherance of statistical work along this line.

In the preparation of the detailed information which has been made available as the result of this lighting survey, the writer has been favored by the kind co-operation of individuals and companies so numerous as to make it impracticable to list them in this connection; it is possible only to express deep appreciation. The loyal disinterested assistance of Mr. N. D. Macdonald of the Electrical Testing Laboratories should be recorded especially.

CORRELATED MATTERS.

In addition to a review of knowledge and practise in respect to the several qualities of light and features of utilization, no discussion of the status of the lighting art would be complete without reference to a number of supplementary factors which have been influential in establishing the present status and which may be looked to for assistance in advancing that status. Prominent among these are educational agencies, commercial organizations in the lighting field, the Illuminating Engineering Society, the attitude of related professions and industries, and photometry.

EDUCATIONAL AGENCIES.

In the way of technical education, universities and colleges are devoting more attention than formerly to the principles of illumination and to photometry. The Johns Hopkins University-I. E. S. lecture course on illumination did much to arouse pedagogic interest in this subject, and the Society's Committee on Illuminating Engineering Education is engaged in an effort to apply the lecture course and promote the further specialization along this line in university education.

It is of prime importance that those who are in a position to influence the design of lighting installations should possess a knowledge of the principles of good illumination. Educational work in this connection is being done on a limited scale by some of the larger manufacturers of lamps and lighting appliances through lectures, the publication of bulletins, and through free consulting engineering advice to customers. A number of the larger lighting companies contribute like service to their customers. The Commercial Section of the National Electric Light Association and the National Commercial Gas Association have done commendable work in the publication of bulletins on certain phases of lighting work. This Society has in course of preparation lectures on several classes of lighting the manuscript of which, accompanied by lantern slide illustrations, is to be made available for presentation wherever required.

Supplementing these efforts is the dissemination of elementary knowledge of good illumination direct to the public through the illumination primer prepared by this Society. Through the efforts of the Society and the co-operation of other organizations this has been issued throughout the country in quantities which aggregate about 250,000.

Knowledge is power. If the simple elementary truths in regard to lighting could be imparted to the public, lighting practise the country over would be advanced tremenduously. Through the several agencies just mentioned it is believed that great strides are being made in this direction.

COMMERCIAL ORGANIZATIONS IN THE LIGHTING FIELD.

In this country the very general enterprise and progressiveness of the leading manufacturers of lamps and lighting appliances is

an asset upon which we are to be congratulated. A number of such organizations maintain laboratories for research work as well as engineering and educational departments. Thus these manufacturing organizations contribute to the advance of the lighting art in three ways. First, by developments made possible through research and invention; second, by the incorporation in the design of their product of the information made available through research in their own laboratories and elsewhere; third, by the general dissemination of the facts which govern good practise.

The progressive attitude of lighting companies, particularly those in the larger cities is likewise commendable and is an important factor in lighting improvement. Through the training of solicitors in lighting fundamentals and the maintenance of illuminating engineering departments, as well as through adherence to the free lamp renewal policy, and the promotion of the use of the most efficient lamps, the contributions of such organizations is large and important.

Another agency not to be ignored is the papers and discussions on illumination which are now included very generally in the programs of electric and gas associations, and to some extent in the programs of professional bodies. Still another agency is the technical journals, which now very generally feature illumination discussions, thereby doing much to promote interest and advance knowledge in illumination affairs.

THE ILLUMINATING ENGINEERING SOCIETY.

In his inaugural address the writer endeavored to review the growth of the society and to state its functions as these are now recognized. At first, scientific discussions predominated because knowledge must precede application, and knowledge of illumination principles was meager. The tendency during recent years has been to supplement the scientific work with practical discussions of lighting practise and with efforts along educational lines.

The only organization in the country which deals exclusively with light, this Society now commands a fair measure of respect from the older national technical societies. It is beginning to realize returns upon its large expenditure of time and effort in

co-operative work with other technical societies. It is undoubtedly one of the principal influences which make for improvement in the lighting art.

THE ATTITUDE OF RELATED PROFESSIONS AND INDUSTRIES.

That the efforts of the Illuminating Engineering Society to improve lighting practise are not lacking in support by other organizations has already been made apparent. It has been indicated that large and progressive corporations are devoting attention to the securing of good illumination as a part of good management and also in connection with welfare work for employees. Lighting companies, both gas and electric, are showing revived appreciation of the importance of the lighting aspect of their business. While in both industries the lighting load is decreasing in proportion to the total load, yet it is recognized that through its lighting service the company comes into contact with the greatest numbers of its public, and excellence of service in this connection is its best possible advertisement.

As an illustration of the present view of lighting companies, it may be said that in the 1913 report of the Lamp Committee of the Association of Edison Illuminating Companies, considerable space was devoted to the importance of promoting good illumination as a means of cultivating good public opinion and conserving revenues.

Perhaps the most interesting and promising features of the replies received in connection with the lighting survey which is described herein is the very evident interest manifested by ophthalmologists throughout the country in the subject of illumination. There is undoubtedly reason to believe that the society will enjoy a larger measure of co-operation from ophthalmologists in the immediate future than has been accorded in the past, and this promises well for improvement in home conditions of lighting.

It must be said that the co-operation of architects in the development of lighting practise is in need of further cultivation. Attempts during the past year to promote further co-operative effort with organizations of architects have come to naught, although encouragement was derived from the cordial attitude met in all cases. It is hoped that a start may be made during the coming

year which will result in securing recognition of mutuality of interest and a greater measure of that co-operative effort which is so necessary to the improvement in lighting practise in buildings in which the architect requires consistent lighting treatment.

PHOTOMETRY.

To the development of a science, proper measurement of the quantities involved is essential. In the growth of knowledge of illuminating engineering, photometry has played an important part. At the present time the status of photometry is definitely established, and very generally recognized. In the manufacture of illuminants photometry is resorted to in rating and efficiency adjustments. In taking the candle-power of gas it finds one of its most general applications. In spite of the increasing strength of the movement to rate gas upon calorific rather than photometric value, the candle-power basis still obtains very generally. In the production of incandescent electric lamps, photometry has found one of its widest applications. The standardization of manufacturing methods, however, is resulting in the abandonment of photometry for the rating of individual Mazda lamps, though the photometry of samples from each batch manufactured still continues to be a regular part of the manufacturing procedure. In the manufacture of other illuminants, photometry is a regular part of the engineering work. In the study of illumination, photometry is practised very generally by illuminating engineers. Accuracies obtained in practise in the various classes of work are of the order indicated in the following table:

TYPICAL ACCURACIES OBTAINING IN PHOTOMETRY OF LIGHT SOURCES WHICH INVOLVES NO LARGE COLOR DIFFERENCES AND NO SERIOUS VARIATIONS IN LIGHT INTENSITY.

	Per cent.
In taking the candle-power of gas	2
In routine rating of carbon and Gem filament lamps	±4
In routine commercial testing of incandescent electric lamps and incandescent gas lamps	±2
In precision photometry	±½

In heterochromatic photometry lower orders of accuracy are encountered, depending upon the extent of the color difference and the methods employed in determinations of intensities. Where material variations in intensities are involved, further in-

accuracies may result due to personal pecularities of observers in recording observations under such conditions. Here again the accuracy which is obtained depends largely upon the extent of the unsteadiness of the light source and the methods of test employed.

A matter of immediate importance to photometricians is the adoption of a standard for use in heterochromatic photometry. In view of the great variety of light sources which are available, and their differing color characteristics, it is important that standards be adopted for working purposes, even though such standards cannot be relied upon for ultimate accuracy. In the adoption of such standards it is believed that the entire laboratory resources of the country should be utilized. This is one of the next important steps to be taken in photometry.

CONCLUSION.

The foregoing is a very inadequate review of the condition in the field which this Society seeks to cultivate. Circumstances beyond control interfered with the writer's intention to make this survey as comprehensive and accurate as possible. Instead of presenting a complete and satisfactory statement which might be placed upon file as a record of the status of the lighting art, it becomes necessary to offer this review as a first step toward the preparation of such a record. However, discussion of the subject with members of this Society, and experience in preparing this review, have brought conviction that a continuation of this effort to compile an adequate compendium of the knowledge of the art and of prevailing practise would result in much good, and would repay the large effort which would be required. It is therefore without apology for the obvious inadequacy of this presentation, but rather with the expressed hope that others may consider the advisability of undertaking a more thorough and authoritative treatment that this survey of lighting conditions is presented.

Our knowledge of the principles of good illumination, though lacking in many essentials, is still considerable. The advances made since the organization of this Society in 1906 are gratifying. The condition for further development of the underlying principles is most hopeful, in view of the investigation and

research which are being carried on by a goodly number of our members. Some of this research in particular, is organized upon such a plan as to warrant a most optimistic view of the probable extension of knowledge in this field in the next few years.

The standard product of manufacturers is improved rapidly in accordance with additions to knowledge of lighting principles. Such improvements in the case of lamps or appliances which have limited life and must be replaced periodically, find their way gradually into most installations. In the case of appliances which do not have to be replaced periodically, such as fixtures, lighting glassware, etc., the improvements are not applied so generally in lighting practise. It is perhaps a misfortune that such appliances do not have a limited life. If fixtures, reflecting glassware, etc., would automatically disintegrate after a reasonable period of service, the commercial incentive offered to manufacturers to improve lighting equipments would be even greater than it is to-day, and the public, would benefit more generally as a result of the improvement which is effected in more recent designs. As it is, new installations benefit, but existing installations in large part obtain little or no advantage from the more recent developments.

Perhaps the biggest problem to be solved by the Society in its effort to secure the general improvement of illumination in all classes of installations is that of displacing antiquated lighting appliances. It would appear that we must look to those who have possible commercial advantage to derive for the display of enterprise which is essential to the general application of better knowledge of illumination principles to general lighting practise. These are the manufacturers of the equipments, and the lighting companies who supply the service. Co-operation between these two classes alone can bring the rapid improvement in the lighting art which conditions demand and which it is the avowed object of this Society to promote. Improvement in artificial lighting which involves a substantial increase in its cost, does not weigh as heavily in the scale of expenditures as would a corresponding increase in many other items of expense.

Given a condition in which it is apparent that the public and a number of important commercial interests will benefit alike by improvement in lighting practise, and a total cost of lighting

which is insignificant in comparison with the benefits conferred by the lighting, and a cost of improvement in such lighting which is small in comparison with the advantages realized through such improvements, it would appear that there is no insurmountable obstacle in the way of attaining the desired result of generally improved lighting. All that is necessary is a co-ordinating influence and the necessary conviction as to the results to be obtained. Herein lies this Society's opportunity.

There is reason to be dissatisfied with progress. Practise lags inexcusably behind knowledge and ideals. It will be conceded that good illumination is greatly to be desired, the same conclusion being reached whether the viewpoint is dominantly commercial, esthetic or humanitarian. In improved lighting, benefits accrue to the public, to consulting engineers, to lighting companies, to manufacturers of lamps, to manufacturers of auxiliaries, and to manufacturers of fixtures. To improve illumination conditions, the public must be aroused to an appreciation of the advantages ever associated with such improvement. This can be done if all the interests just mentioned can combine and co-operate to support the propaganda of this Society. The enthusiasm and conviction which would necessarily characterize such a movement would constitute an irresistible force which would be certain to accomplish the purpose of awakening public interest and bringing conviction of the benefits which would be sure to follow. How are we to enlist the support and co-operation of the commercial interests whose participation in such a forward movement is essential to its success? This is the practical question which this Society must answer. Already the beginning has been made, and the Society now enjoys a measure of sympathy and support from the commercial interests with which it has never before been favored. However, it is necessary to convince the lighting industry of the potentialities of the situation before any really effective campaign can be waged on a large scale. What measures can be adopted for bringing this about? Two are suggested herewith.

First, it is recommended that the Society supplement its splendid work of research, discussion and education, by devoting special considerations to ways and means of adopting its work to

meet the requirements of the commercial interests to which we must look for extension of improved lighting practise. A committee on commercial application would doubtless do much to further this cause.

Second, the members of this Society individually may accomplish results which in the aggregate will be far-reaching in their effect in popularizing good illumination. Lighting which is inadequate, inartistic, unhygienic or inefficient is often observed in the homes of the members of this Society. Comment brings some such reply as that "He that makes shoes goes barefoot himself." It is submitted that this state of affairs is a reproach under which no member of this Society should remain. It behooves each of us to combine practise with precept. Surely there is no member of this Society who does not feel assured that by lighting his home properly, he will contribute to the happiness and welfare of the members of his family, perhaps more largely than is possible with a similar expenditure in any other way. Then what excuse can there be for the member of this Society who presumably is informed in these matters, who recognizes the importance and the possibilities of good lighting, and yet permits the retention in his home or office of improper lighting equipments?

Furthermore, it may be assumed that most of the members of this Society have more or less commercial interest in the extension of good lighting. On narrower and more sordid grounds, is it not incumbent upon such members to promote good lighting practise by example?

Should we not attend to the installation in our homes of modern lighting equipment which is in reasonable conformity with the latest tenets of illuminating engineering? Also should we not employ such equipment freely, to the end that in our homes we may at all proper times exemplify the faith which is within us? How great an influence upon the community would be exerted if every man who is interested in the furtherance of our propaganda would so illuminate his home that it would demonstrate to all who observe, the advantages of good lighting! It ought to be possible to say of the members of this Society—"By their lighting ye shall know them."

ANNUAL REPORT OF THE GENERAL SECRETARY FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1913.

The past fiscal year of the Society has been one of general expansion. The educational and co-operative work started in the previous year has been continued and extended, while new lines for developing the Society and enlarging its sphere and influence have been followed with gratifying results. Perhaps in no other year has such a general concerted effort been made to place the Society on a broad and firm basis for future service. Some of the results achieved are briefly recounted in the following report.

I. FINANCES.

The financial status (see auditor's report on another page of this issue) of the Society has been improved somewhat by the acquisition of sustaining members. Although the expenses have increased because the work of the Society has been conducted along more extensive and useful lines, the revenue has been slightly in excess of the expenses.

Under the following captions, Income and Expense statistics are given to show the extent of the various sources of income and expense. The per cent. figures which are fairly indicative may be used for comparisons with other years; but the amounts are not to be compared with similar figures without considering the fact that the past fiscal year was of only nine months duration.

Income.—About 63 per cent. of the total income was derived from members' dues, and 8 per cent. from sustaining members. Both sources netted \$5,897.08, or 71 per cent. of the total revenue. Only about 28 per cent. or \$2,359.41, therefore, was obtained from other sources, including \$1,097.14 or approximately 13 per cent. from advertising.

Expenses.—An analysis of the expenses shows that \$3,768.84 or 46 per cent. was expended for general office salaries, rent, supplies, etc. The next largest item was that of the TRANSACTIONS, \$1,844.72, or 22 per cent. of the total expenses.

The latter sum is relatively 25 to 30 per cent. higher than the cost of the TRANSACTIONS for a similar period of last year, on

account of the new form and style which was adopted at the beginning of the present year.

Exclusive of the latter two items, $2,562.09, or 31 per cent. was required for general Society expenses.

Another interesting fact is that the total revenue from the dues of members and sustaining members, amounted to 72 per cent. of the total expenses. Without the revenue from sustaining members, the income from dues was only 63 per cent. of the total expenses.

The surplus of $1,453.94 as of January 1, 1913, has been increased to $1,865.40 as of September 30, 1913.

The total assets of the Society are shown to be $6,838.18, against which there are liabilities of $4,972.78.

II. MEMBERSHIP.

A gain was also made in the membership. One hundred and forty-eight applications and re-instatements were received; while the defections totaled 86—a net gain of 62 members.

In addition to the foregoing increase 21 sustaining members, whose names are listed below, were elected. This class of membership was created by a change in the constitution which became effective at the beginning of the present fiscal year. It is gratifying to note in passing the number of organizations which have so promptly applied for membership.

Name	Date of election
Electrical Testing Laboratories	3/14/13
Holophane Works of General Electric Company	3/14/13
The Edison Electric Illuminating Company of Boston	3/14/13
The New York Edison Company	3/14/13
The Philadelphia Electric Company	3/14/13
The Edison Electric Illuminating Company of Brooklyn	4/11/13
Commonwealth Edison Company	4/11/13
Macbeth-Evans Glass Company	4/11/13
Westinghouse Lamp Company	4/11/13
Boston Consolidated Gas Company	4/11/13
National Electric Lamp Association	4/11/13
Benjamin Electric Manufacturing Company	4/11/13
United Electric Light & Power Company	5/ 9/13
Welsbach Company	6/13/13
Consolidated Gas, Electric Light and Power Company of Baltimore	6/13/13
Alexalite Company	9/23/13

Name	Date of election
Cooper-Hewitt Electric Company	9/23/13
Jefferson Glass Company	9/23/13
Little Rock Railway & Electric Company	9/23/13
Pittsburgh Lamp, Brass & Glass Company	9/23/13
The Leeds and Northrup Company	9/23/13

The sources of membership gains and losses are shown in the tabulation given below:

	Sections					Un-affiliated and foreign
	Phila-delphia	New York	Chicago	Pitts-burgh	New England	
Total number of members at beginning of year, January 1, 1913	338	399	209	159	95	135
Total applications received	13	59	33	14	2	27
Defections (resignations and deceased members)	9	29	15	13	11	9
Total number at end of year	342	429	227	160	86	153

It will be observed that the only loss of membership was in the New England Section. From territories without the jurisdiction of sections, 27 applications and 9 defections have been received, making a net gain of 18 members.

Through death the following members were lost:

Carrigan, Howard F.
1538 First National Bank Building, Chicago, Ills.
Douglass, David
Eau Claire Gas Light Company, Eau Claire, Wis.
Schniewind, Dr. F.,
6 Church Street, New York City.

A geographical distribution of the Society's members is shown in the following tabulation:

ILLUMINATING ENGINEERING SOCIETY MEMBERS.

United States.

	Members	Sustaining members
Alabama	2	..
Arkansas	..	1
California	19	..
Colorado	7	..
Connecticut	13	..
District of Columbia	17	..
Florida	3	..

United States—(continued).

	Members	Sustaining members
Georgia	7	..
Illinois	129	2
Indiana	20	..
Iowa	10	..
Kansas	6	..
Kentucky	2	..
Louisiana	4	..
Maine	4	..
Maryland	21	1
Massachusetts	76	2
Michigan	21	..
Minnesota	9	..
Missouri	17	..
Nebraska	4	..
New Hampshire	4	..
New Jersey	91	3
New York	339	5
North Carolina	2	..
Ohio	92	2
Oklahoma	2	..
Oregon	7	..
Pennsylvania	348	4
Rhode Island	5	..
South Carolina	2	..
South Dakota	2	..
Tennessee	1	..
Texas	4	..
Utah	4	..
Vermont	1	..
Virginia	6	1
Washington	5	..
West Virginia	3	..
Wisconsin	26	..
	1,335	21

Members not in the United States.

Canada	21
England	17
France	3
Germany	6
Hawaii	1
Japan	1
Mexico	1
Panama	1
Philippines	2
South America	8
Spain	1
	62

Total Members .... 1,335 + 62 = 1,397

III. SECTIONS.

The following table of comparisons gives a bird's eye view of the work and progress of the several sections of the Society:

	Philadelphia	New York	Chicago	Pittsburgh	New England
Total members Sept. 30, 1913	342	429	227	160	86
Net changes during year	+4	+30	+18	+1	−9
Number of meetings held	6	5	5	6	4
Number of papers printed in TRANSACTIONS	2*	5	1*	3*	3
Average attendance at meetings	121	144	68	37	35
Total expenses, 9 months	$130.88	$245.03	$217.04	$149.73	$53.78

* One paper pending publication.

Each one of the several sections has had one or more joint meetings with other Societies. These meetings have for the most part been devoted to popular and elementary discussions of lighting subjects. Consequently the contributions to the TRANSACTIONS have been small compared with previous years. These meetings, however, which were intended to be of an educational character, have strengthened the prestige of the Society and won a great deal of respect for the science and art of illumination from many societies which have hitherto had only a vague idea of what is illuminating engineering. In general the success and results of section activities have been very gratifying.

LOCAL SECRETARIES.

To extend the work and influence of the Society to those cities which do not have sections, several local secretaries have been appointed. The local secretaries are:

State	City	Name and Address
California	Los Angeles	R. H. Manahan, City Electrician
California	San Francisco	F. Emerson Hoar, Railroad Commission of State of California, 832 Market Street.
Colorado	Denver	G. E. Williamson, Denver Gas & Electric Light Co.
Georgia	Atlanta	William Rawson Collier, Georgia Railway and Light Co.

State	City	Name and Address
Minnesota	Minneapolis	G. D. Shepardson, University of Minnesota, Minneapolis, Minn.
Minnesota	St. Paul	A. L. Abbott, Northwestern Electric Equipment Co.
Washington	Seattle	Fred. A. Osborn, University of Washington.

It is expected that these representatives will endeavor to promote occasional meetings under the joint auspices of the Illuminating Engineering Society and local organizations with a view to fostering interest in lighting matters. Such activities should lead eventually to the organization of sections in the given cities or territories.

TRANSACTIONS.

Eighteen papers on various phases of illuminating engineering have been published in the TRANSACTIONS during the past year. From the list of titles given below it will be noted that these papers include a wide range of subjects. Taken together they are fairly indicative of the field covered by the science and art of illumination.

Department Store Lighting.
Influence of Colored Surroundings on the Color of the Useful Light.
The Theory of Mercury-Vapor Apparatus.
Tests for the Efficiency of the Eye under different Systems of Illumination, and a Preliminary Study of the Causes of Discomfort.
Street Lighting with Ornamental Luminous Arc Lamps.
Some Phases of the Illumination of Interiors.
Illumination and Eye Strain.
Home Illumination.
A Photometer Screen for use in Tests of Street Illumination.
The Flame Carbon Arc Lamp.
The Illumination of Motion Picture Projectors.
Street Lighting of Greater New York.
The Illumination of Passenger Cars.
Some Home Experiments in Illumination from Large Area Light Sources.
Gas Lighting in an Exhibition Hall.
Metal Reflectors for Industrial Lighting.
Vision as Influenced by the Brightness of Surroundings.
A Practical Solution of the Problem of Heterochromatic Photometry.

Nearly all the papers and many of their attending discussions have laid more or less stress upon the hygienic aspects of light and illumination. Greatest interest has been manifest in those papers dealing with the commercial application of the scientific principles to lighting practise, say in the design or re-design of installations.

Not any of the papers presented at the 1913 convention are included in the foregoing list.

Beginning with the first of the year the TRANSACTIONS was published in a new form. The general make-up of the publication has been improved. Paper free from glare has been used throughout. The new style has increased the cost of publication between 25 and 30 per cent.

COMMITTIES.

Some twenty-five permanent and temporary committees have conducted the work of the society with rather unusual activity. A brief record of the success of their work is given in the following paragraphs.

1913 *Convention Committee.*—The 1913 convention—thanks to the good work of the committee—surpassed in general excellence any previous convention. The attendance of out-of-town delegates was considerably larger than that of any previous year. An excellent program of papers, well balanced with commercial and scientific subjects, lively discussions, and a generous complement of amusement combined to make the convention an unusual success.

Committee on the Glore from Reflecting Surfaces.—This committee followed up the work which it started in 1912. It has confined its efforts chiefly to giving publicity to the evils arising from the glare of reflected surfaces, especially from glazed paper, and to the collection of data and information pertaining to the use of unglazed paper. An eight-page leaflet entitled "Glare" was published and circulated. The leaflet consisted of glazed and unglazed paper and was designed primarily for the purpose of emphasizing the evils of glare from paper. The committee has communicated with a number of leading publishers of

books and periodicals. Several publishers have already adopted unglazed paper through the efforts of the committee. In the opinion of the committee glazed paper will be eliminated from general use as soon as this change can be effected without an unreasonable increase in cost. With an increased demand for unglazed paper, it is very likely that an entirely satisfactory paper will be forthcoming.

Committee on Research.—The committee has drafted some excellent plans for its procedure. If these are pursued even to a small degree in the future, noteworthy results must accrue. Briefly the committee has planed to make its services (1) co-operative and advisory, and (2) initiatory. The committee favors co-operation with several committees of the Society and sister societies, with departments of universities, research laboratories and individuals, when matters of research are concerned. The committee proposes (*a*) to suggest research problems to parties desirous and competent to do valuable work, (*b*) to compile a list of subjects in which research seems to be advisable, and (*c*) to arrange a bibliography on the various phases of illumination. While the fulfillment of these functions and plans has not progressed sufficiently to warrant definite achievements, results may be expected in the future.

Committee on Collegiate Education.—The work of this committee has been conducted in accordance with the following plan; (1) to determine which colleges and universities are giving any attention to illuminating engineering; (2) to find out exactly the character and extent of such work as is being done; (3) to call attention of college authorities to the importance of greater and adequate instruction in all matters pertaining to the use of light, with a view to (*a*) bringing about the introduction of courses in illumination, and (*b*) looking to the extension and amplification of present courses. To ascertain the status of illuminating engineering in the curricula of colleges, the committee has sent a letter to a number of college presidents, asking for information, in regard to courses in illumination in their institutions. A sufficent number of returns have not yet been received from these inquiries to warrant a statement at this time.

Committee on Reciprocal Relations with other Societies.—The excellent work of this committee, which was appointed for the first time in 1912, has been continued during the present year. The committee has been in touch with some twenty or thirty societies and has arranged joint meetings with several of them, notably the American Gas Institute, The National Commercial Gas Association, The National Electric Light Association, The American Academy of Medicine, the School Hygiene Congress and the American Medical Association. In acquainting other organizations with the objects and province of the Illuminating Engineering Society this committee has rendered a service of great value.

Committee on Sustaining Membership.—Through the efforts of this committee the companies whose names appear on a previous page all became sustaining members within a period of five months. The revenue from sustaining membership has increased the funds of the society so that the work on a more enlarged and efficient scale might be started.

Committee on Nomenclature and Standards.—The committee has held several meetings, and has been in touch with the standards committees of several American and foreign societies, which are interested in the science and art of illumination. It has formulated plans for aiding the formation of an international photometric commission. It has also proposed a number of revised definitions of standards and of terminology, which have been transmitted to the International Photometric Commission and interested societies.

Committee of Factory Lighting Legislation.—Appointed this year for the first time to consider matters of legislation where illumination is concerned, this committee has undertaken and rendered valuable service in a field which heretofore has received scant and insufficient attention. Upon invitation, its members attended a meeting of the New York State Factory Commission and made a number of recommendations relating to the lighting of factories and workrooms, with special reference to adequacy and quality of illumination. A bill incorporating these recom-

mendations was submitted to the Legislature and became a law in New York State on October 1, 1913. The committee was also represented at a conference of the Heights of Buildings Committee of the Board of Estimate and Apportionment of the City of New York, at which the illumination of interiors by daylight and by artificial light was discussed.

Section Development Committee.—During the year the committee completed work on the preparation of a guide on section management which had been started in the previous year. The guide constitutes a convenient arrangement of notes and suggestions which tells in a general way how the affairs of section may be advantageously conducted. It is believed that it will go a long way toward promoting co-operation, co-ordination and efficiency in the work of the society. Heretofore new boards of managers have had to undertake the management of sections with a very indefinite knowledge of the duties and responsibilities to be discharged. Now any board, though it be entirely new, may in an hour or two become familiar with what has been found to be good procedure and what work was done by the previous board. Hereafter it is likely that the preliminary plans and details incidental to the beginning of each season will be arranged with greater dispatch. Copies of the guide have been issued to the members of all the section boards as well as to a number of officers of the society.

Committee on Finance.—The Committee on Finance has exercised general supervision over the affairs of the Society. It has approved all appropriations and disbursements.

Committee on Illumination Primer.—A few slight revisions were made in the first edition of the primer which was published last fall. Of this revised edition approximately a quarter of a million copies have been printed. Over 220,000 copies of the latter edition were sold to lighting companies throughout the country for distribution to their customers. The primer has been widely advertised and commended in trade, and other pournals both in this country and abroad. No work of the Society has met with greater approval on the part of the public and the lighting industry in general. Certainly no publication of its kind has

done more to spread the gospel of good illumination, particularly in the way of creating a desire for better standards of illumination.

Committee on Papers.—The Committee on Papers has passed upon all papers submitted to the Society within the past year. It has earned the distinction of having arranged for the 1913 convention a program which has been pronounced the best balanced set of papers ever presented before a meeting of the Society.

Committee on Editing and Publication.—While practically all the publication work of the Society has been done in the general offices, the Editing Committee has served in an advisory capacity and passed upon from time to time questions involving the editorial policy of the Society. A guide for authors, setting forth the editorial requirements and style of papers has been prepared for distribution. The committee believes that this pamphlet will promote a degree of desirable uniformity in all papers and at the same time obviate considerable expense in publication.

Committee on Advertising.—In accordance with instructions from the Council, the committee has made no special attempt to increase the amount of advertising contracted for during the year 1912. The net income derived from advertising, $1,097.14, was relatively, a little higher than that for a corresponding period of 1912.

Committee on Membership.—No active general campaign for increasing membership has been conducted. Through the chairman of the various section Membership Committees, a conservative effort was made to bring into the Society those members who are most likely to contribute to and profit by its work. Durthe year the total membership was increased by 62 members. One hundred and forty-eight applications and reinstatements were received largely as a result of the committee's efforts.

Committee on Progress.—The work which this committee did is indicated by the excellent and comprehensive report of progress in the field of illuminating engineering during the past year, which was submitted at the convention. The report* sets a high standard of comparison for all future progress reports.

* TRANS. I. E. S., Vol. VIII, No. 7 (October, 1913), p. 323.

Committee on Joint Session with the American Gas Institute.—This committee was appointed solely for the purpose of arranging an illuminating engineering session at the annual meeting of the American Gas Institute which was held in Richmond in October, 1913. For this session the committee arranged for a number of papers and talks on various phases of illuminating engineering and the work of the Society itself.

Committee on Joint Meeting with the International Congress of School Hygiene.—A session at which several papers on the hygienic aspects of light and illumination were presented was arranged by the committee. The Congress manifested a great deal of interest in this particular session.

Committee on 1915.—This committee was appointed for the purpose of considering the advisability of holding the 1915 convention of the Society in San Francisco during the Panama Pacific Exposition. No definite recommendations were made because the committee believed the time of that convention was too far off.

Committee on Popular Lectures.—The Committee on Popular Lectures was appointed at the beginning of the year to make available popular lectures on good lighting practice. With such lectures it is hoped that it will be possible to create on the part of the public a better appreciation of good lighting and ultimately raise the standards of illumination. While it is planned to cover other fields of lighting, the first efforts will be confined to residence, store, industrial lighting and office lighting. Sub-committees have been appointed—one for each of these four classes of lighting, the members of which are experts familiar with the best practice. In order that lectures may be useful, without evincing commercial prejudice, a special endeavor has been made to balance the committees with reference to the interests represented that they may be free from any commercial bias. It is proposed that each of these sub-committees shall prepare one or more lectures on the subjects assigned. Photographs from which lantern slides may be made will be collected to illustrate by example what is considered good lighting practise, and on the

other hand to emphasize the evils of poor illumination. A careful selection of the committees has just been completed and it is planned to have available within the next month or two at the general offices of the Society, a series of lectures which may be loaned to societies and associations, lighting companies, both gas and electric, and other organizations which are interested in illumination.

To the *Committee of Tellers* which counted with patience and care the ballots of the annual election, and to the *Committee on the Formation of a Lake Erie Section*, which considered and reported the possibilities of such a section, special thanks is due. The latter proposal while encouraging was left for future development.

Delegates.—During the year a number of representatives have been appointed, upon invitation, to boards and committees of other organizations, (International Gas Congress, Committee on Organization International Electrical Congress, American Association for the Conservation of Vision, United States National Committee of the International Commission on Illumination) in order that the Society might keep in touch with work with which it is concerned. The services of these representatives deserves the thanks of the Society.

GENERAL.

Here, at the end of another year, there is cause to look back with grateful appreciation upon praiseworthy efforts of the officers, committeemen, section boards, and many other members who have given unstintingly of their time and thought to the work and objects which the Society seeks to promote. The measure of success attained must be ascribed entirely to their work.

Worthy of record, also, is the encouraging co-operation which has been obtained from sister organizations in promoting what has been aptly called the gospel of better illumination. There have been numerous evidences of increasing and greater respect for illuminating engineering or the science and art of illumination as many prefer to call it. Bonds of common interest between the I. E. S. and many societies have been established and strengthened.

Further, the initial activities of the German Illuminating Engineering Society, and the promise of organization of a French society before long, have attracted world-wide attention. In a word, illuminating engineering is gradually coming into its own. Let those who wish predict when illuminating engineering will take its place among the firmly established professions. For the present it is gratifying enough to observe the rapid advancement in that direction.

Some reason there might be for referring in this report to the generally consistent progress, the notable developments, and the numerous examples of scientifically designed installations, in the lighting field during the past year if all these were not already chronicled elsewhere.

Respectfully submitted,

JOSEPH D. ISRAEL,
General Secretary.